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Bolze et al.

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(54) **FORMATION FLUID SAMPLING APPARATUS AND METHOD**

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(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(51) **Int. Cl.**^{7} **E21B 49/00**; E21B 49/08

(52) **U.S. Cl.** **166/264**; 166/167; 175/59

(58) **Field of Search** 166/163, 165, 166/167, 264; 175/20, 58, 59

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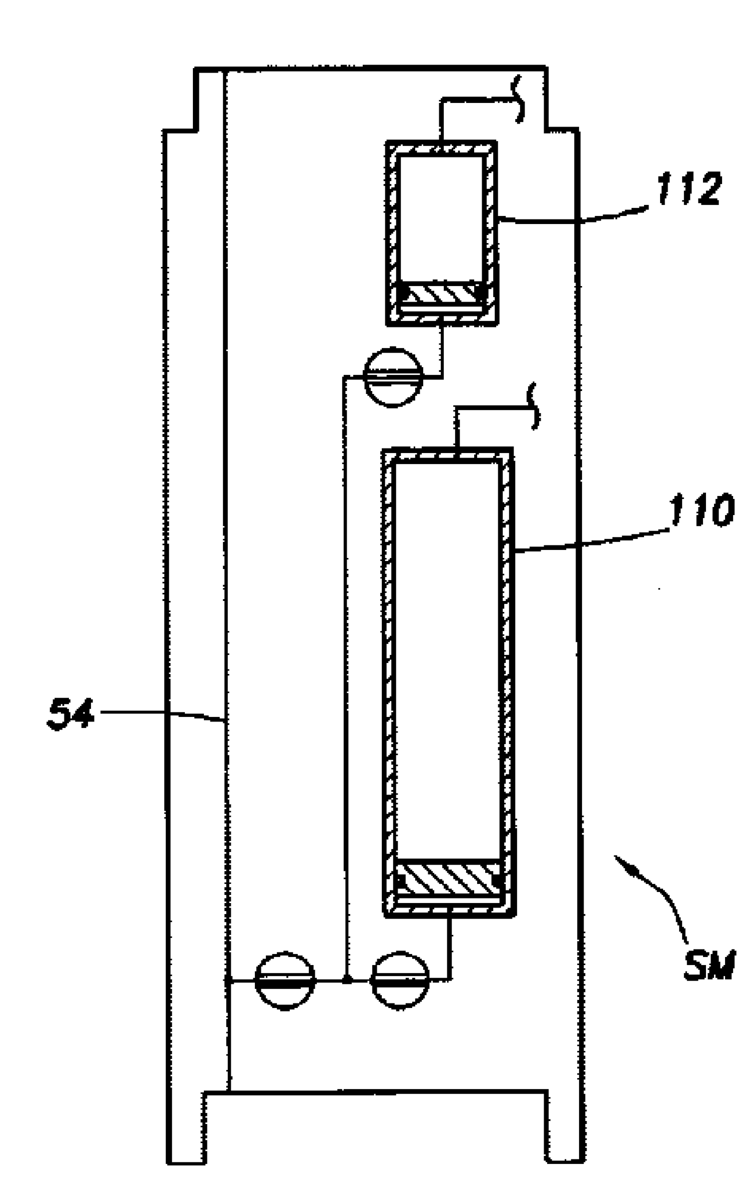
(57) **ABSTRACT**

A sample module is provided for use in a downhole tool to obtain fluid from a subsurface formation penetrated by a wellbore. The sample module includes a sample chamber carried by the module for collecting a sample of formation fluid obtained from the formation via the downhole tool, and a validation chamber carried by the module for collecting a substantially smaller sample of formation fluid than the sample chamber. The validation chamber is removable from the sample module at the surface without disturbing the sample chamber. A sample chamber is also provided that includes a subtantially cylindrical body capable of safely withstanding heating at the surface, following collection of a formation fluid sample via the downhole tool and withdrawal of the sample chamber from the wellbore, to temperatures necessary to promote recombination of the sample components wihtin the chambers. Additionally, the body is equipped so as to be certified for transportation. At least one floating piston is slidably positioned within the body so as to define a fluid collection cavity and a pressurization cavity, whereby the pressurization cavity may be charged to control the pressure of the sample collected in the collection cavity. A second such piston may be provided to create a third cavity wherein a buffer fluid may be utilized during sample collection. Metal-to-metal seals act as the final shut-off seals for the sample collected in the collection cavity of the body. A method related to the use of the sample module and sample chamber described above is also provided.

31 Claims, 13 Drawing Sheets



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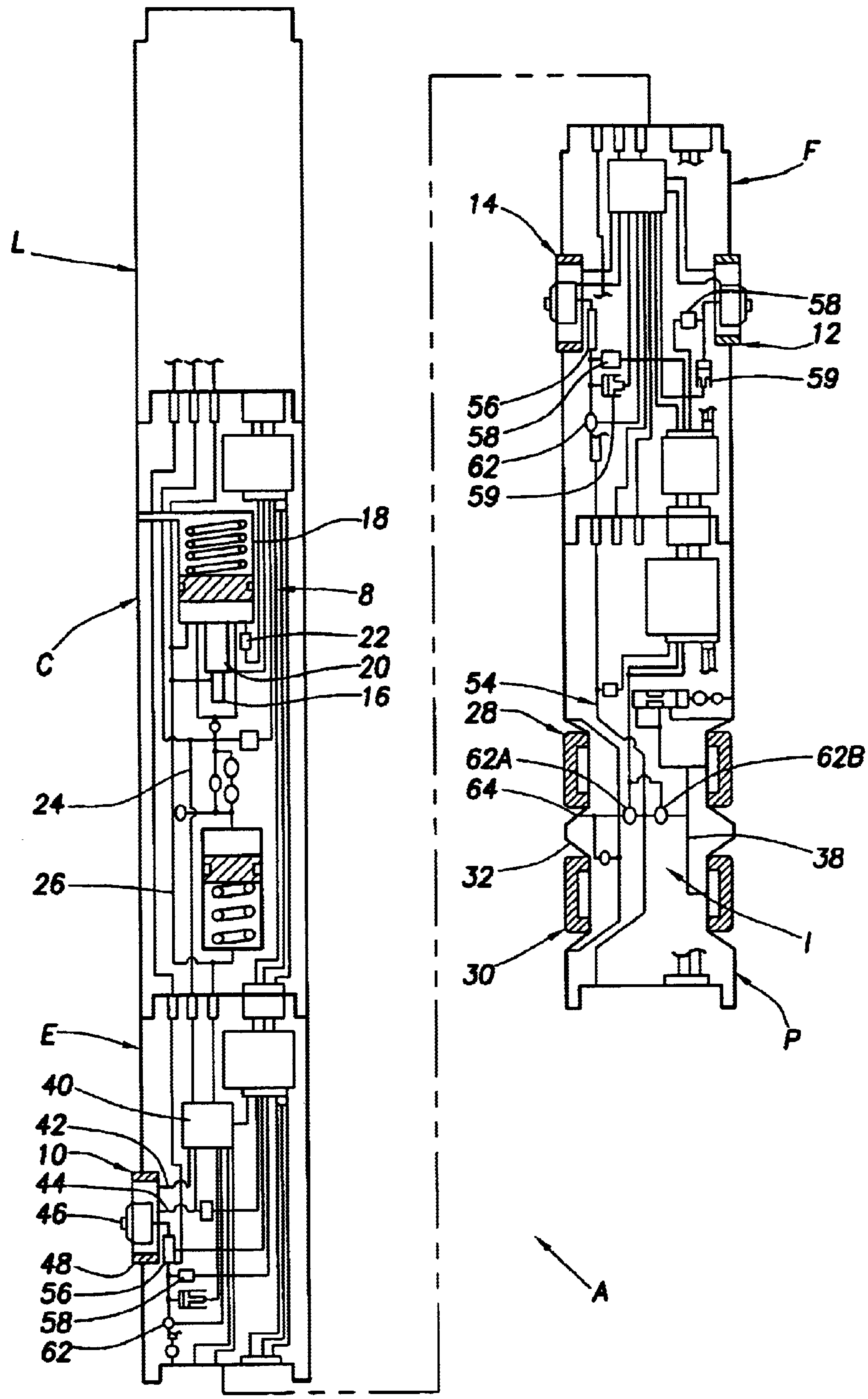


FIG. 1
(PRIOR ART)

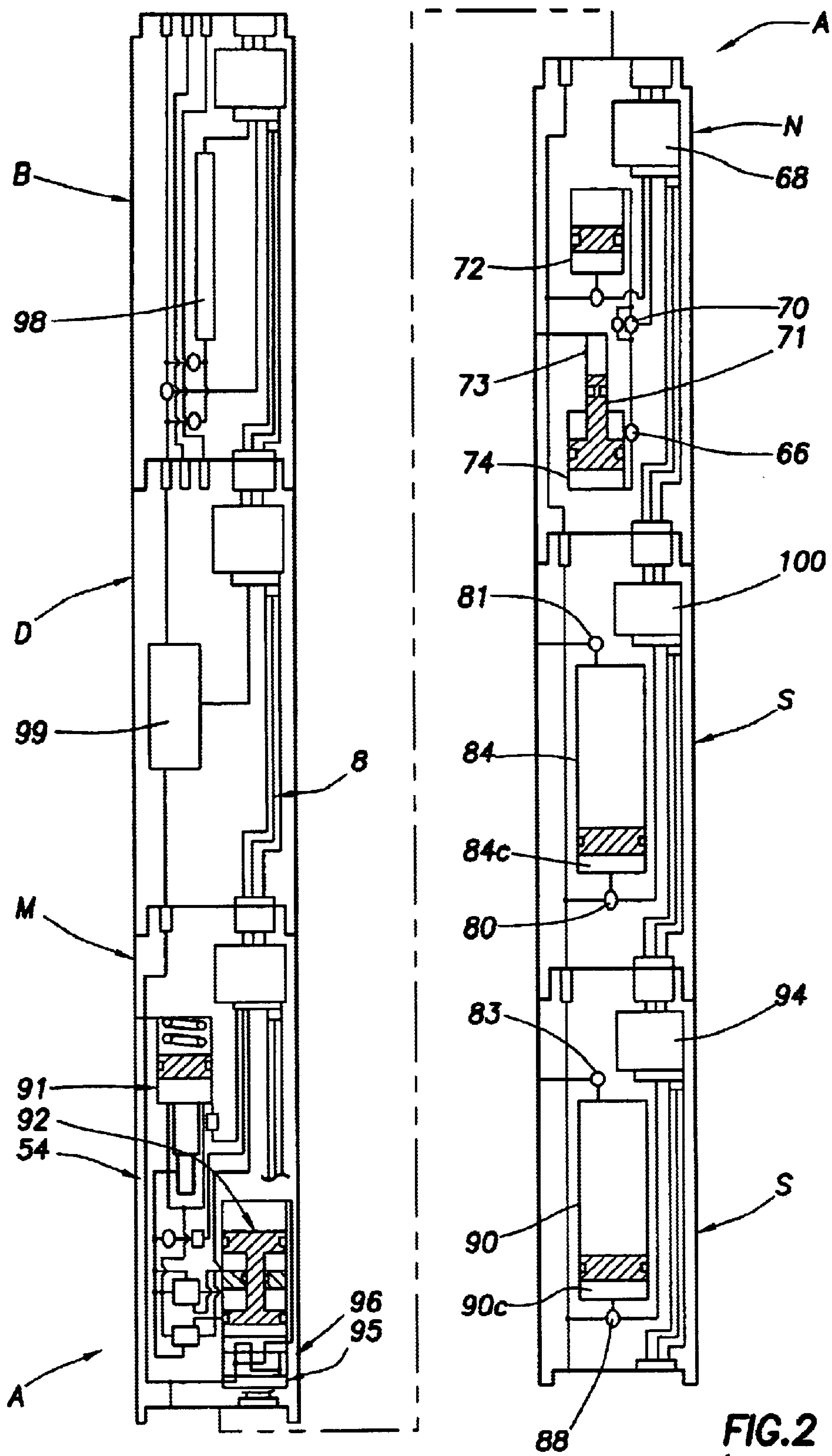


FIG.2
(PRIOR ART)

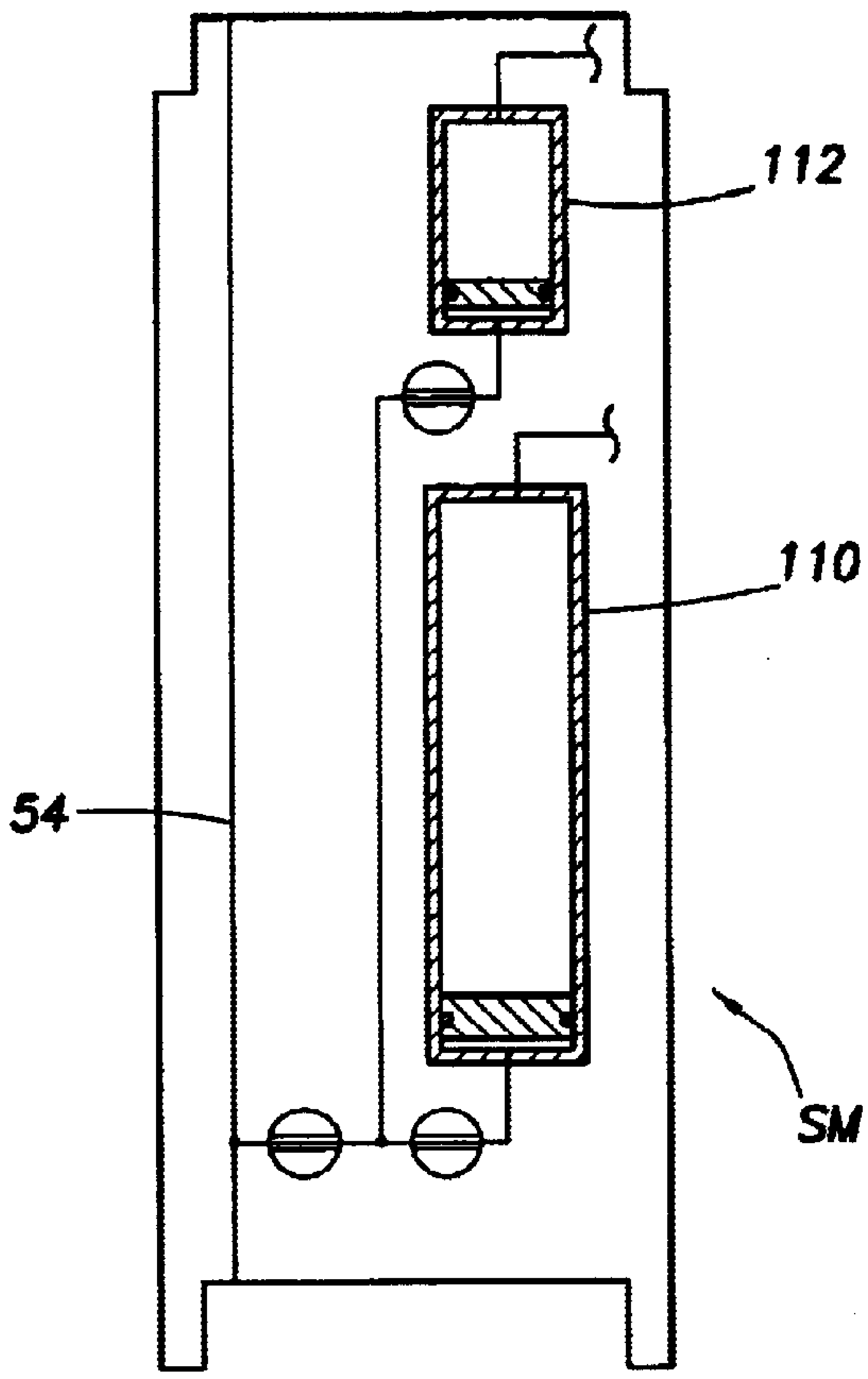


FIG.3

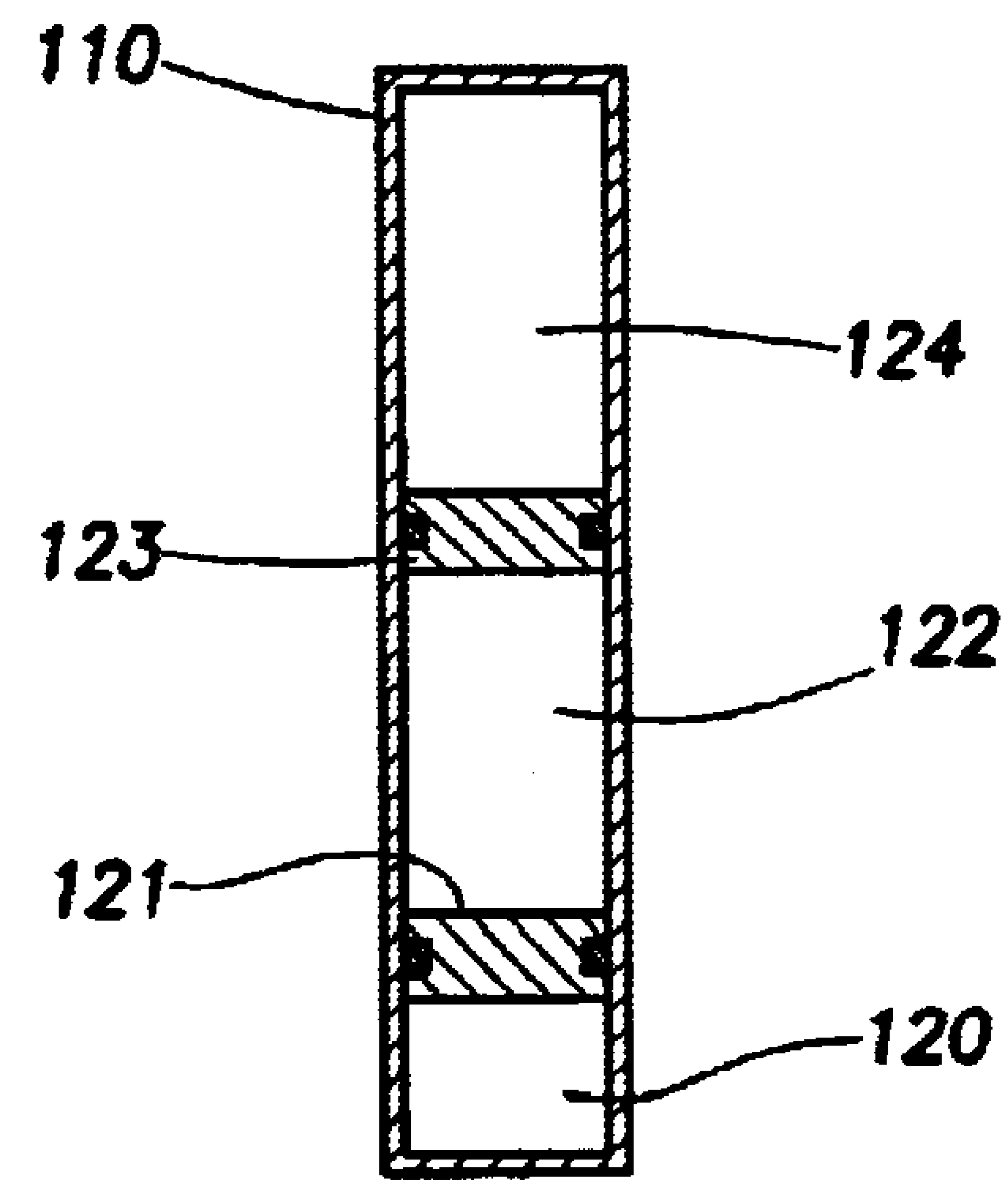


FIG.4

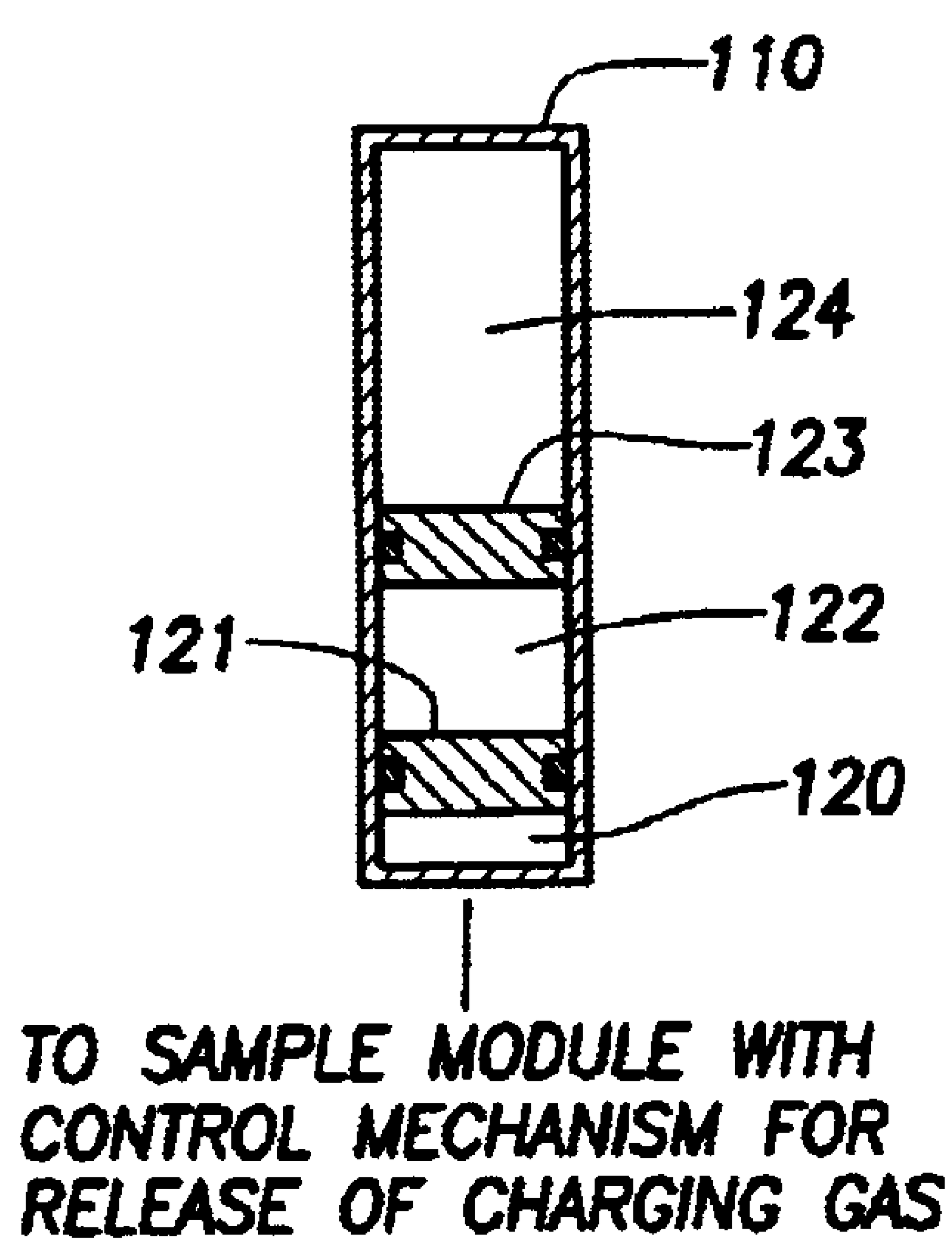


FIG.5A

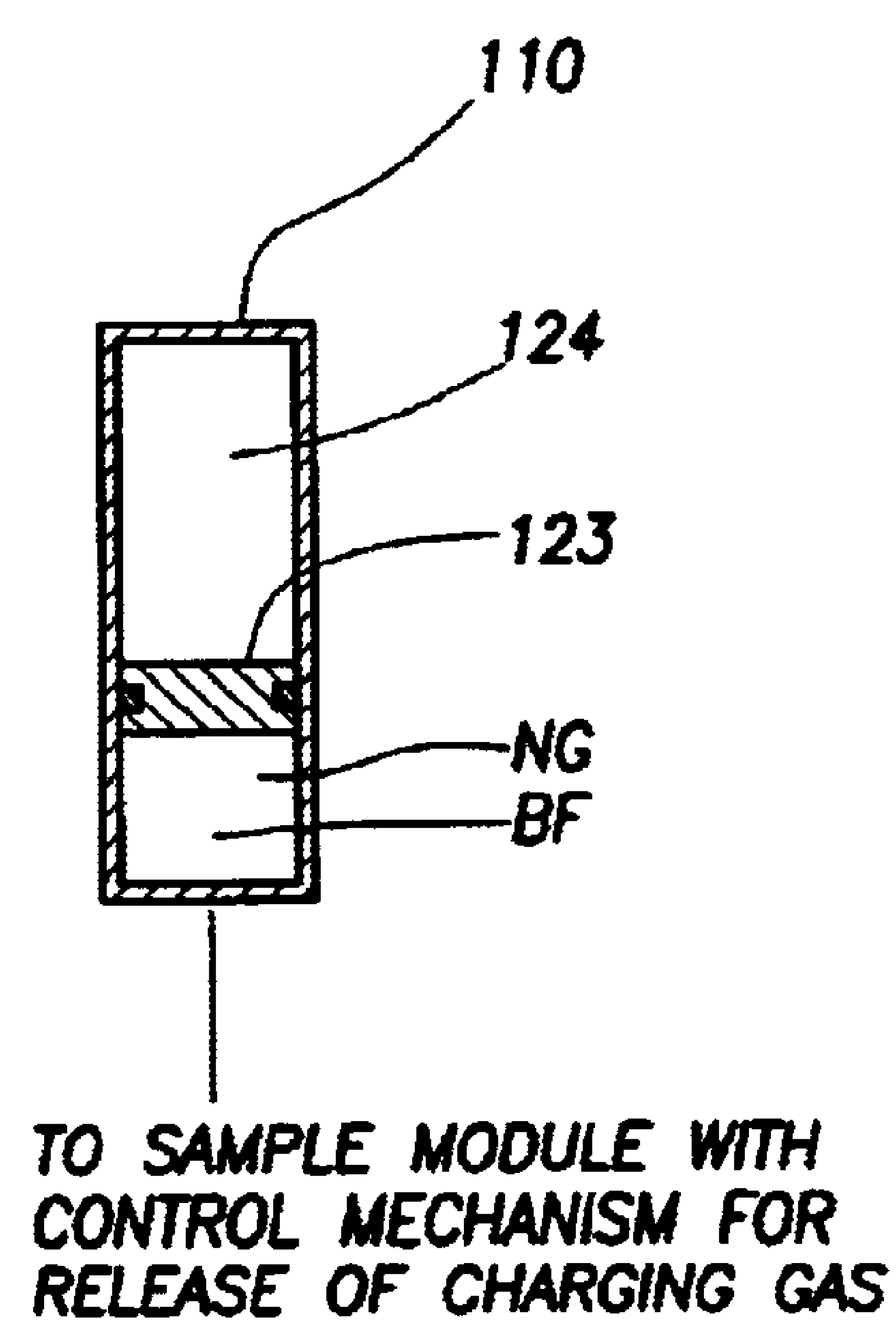
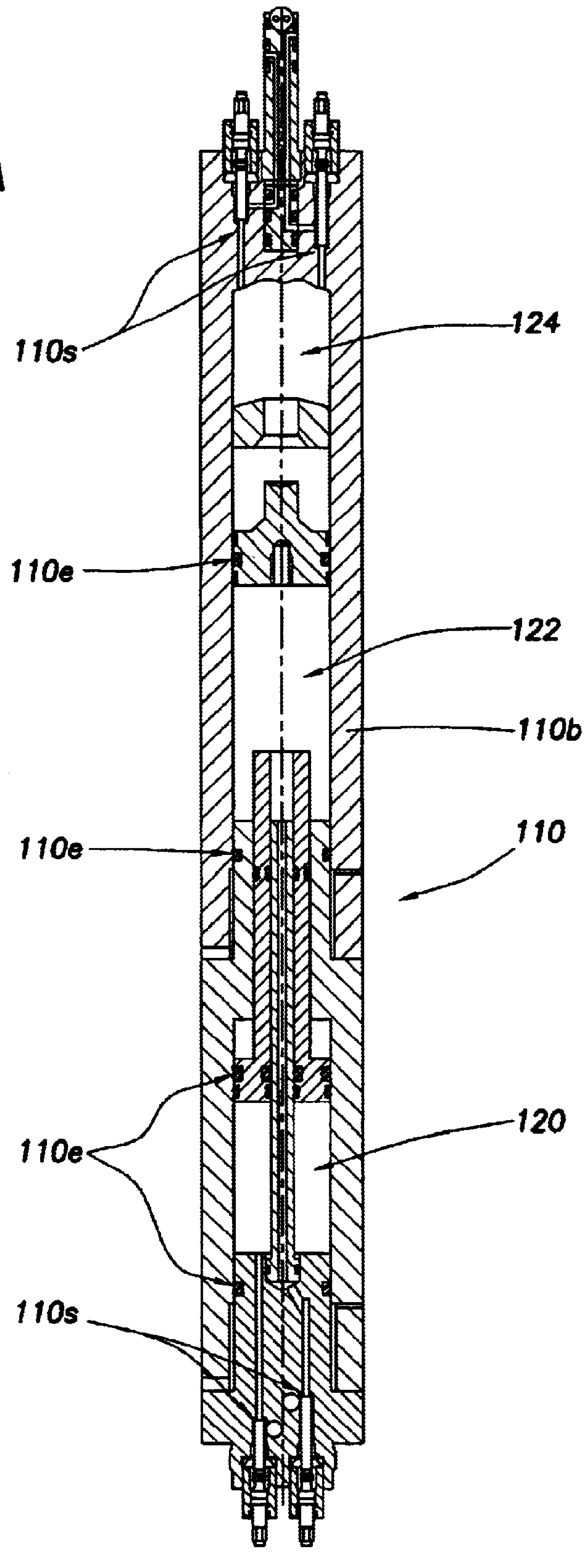


FIG.5B

FIG.3A



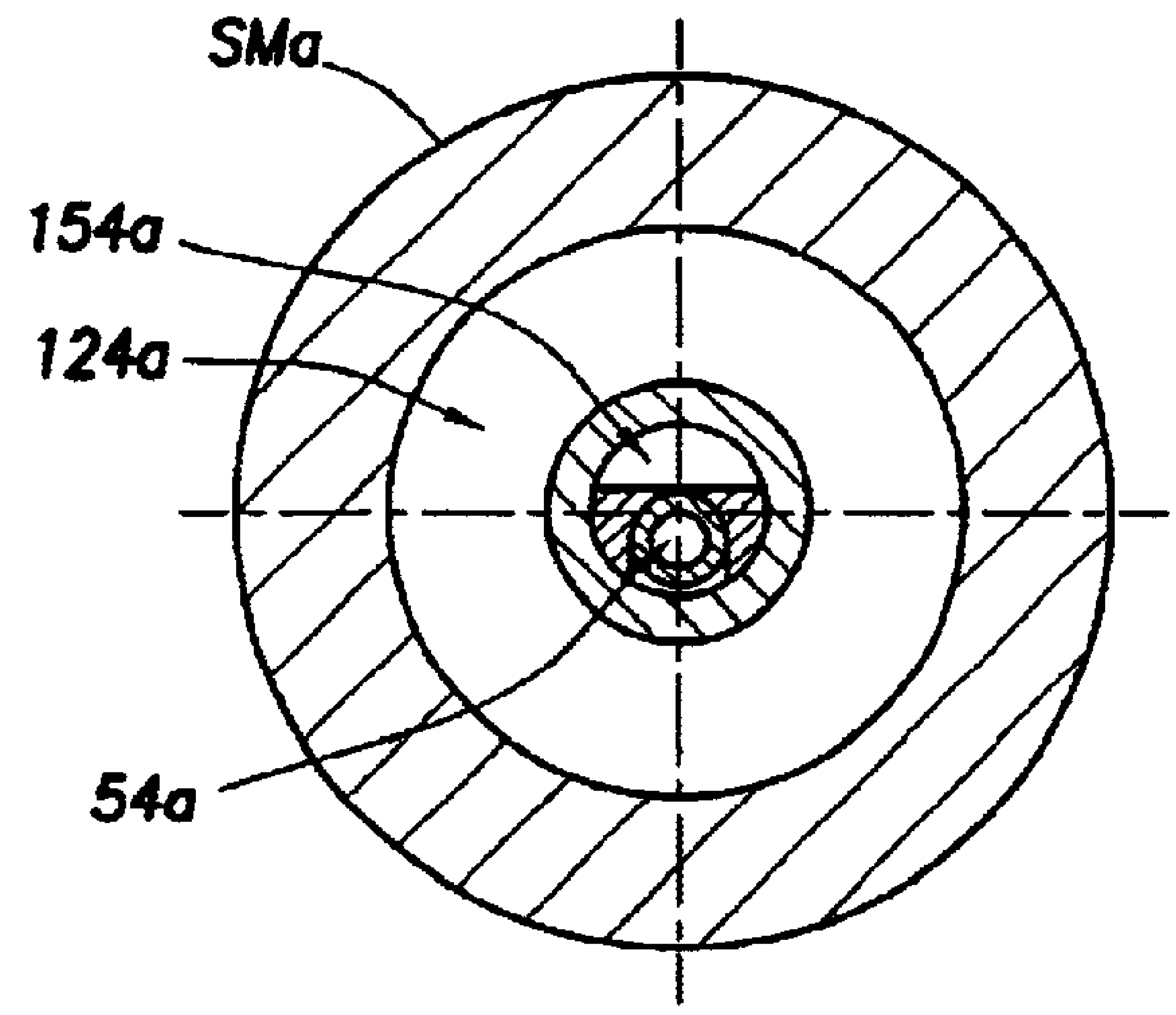


FIG.6A

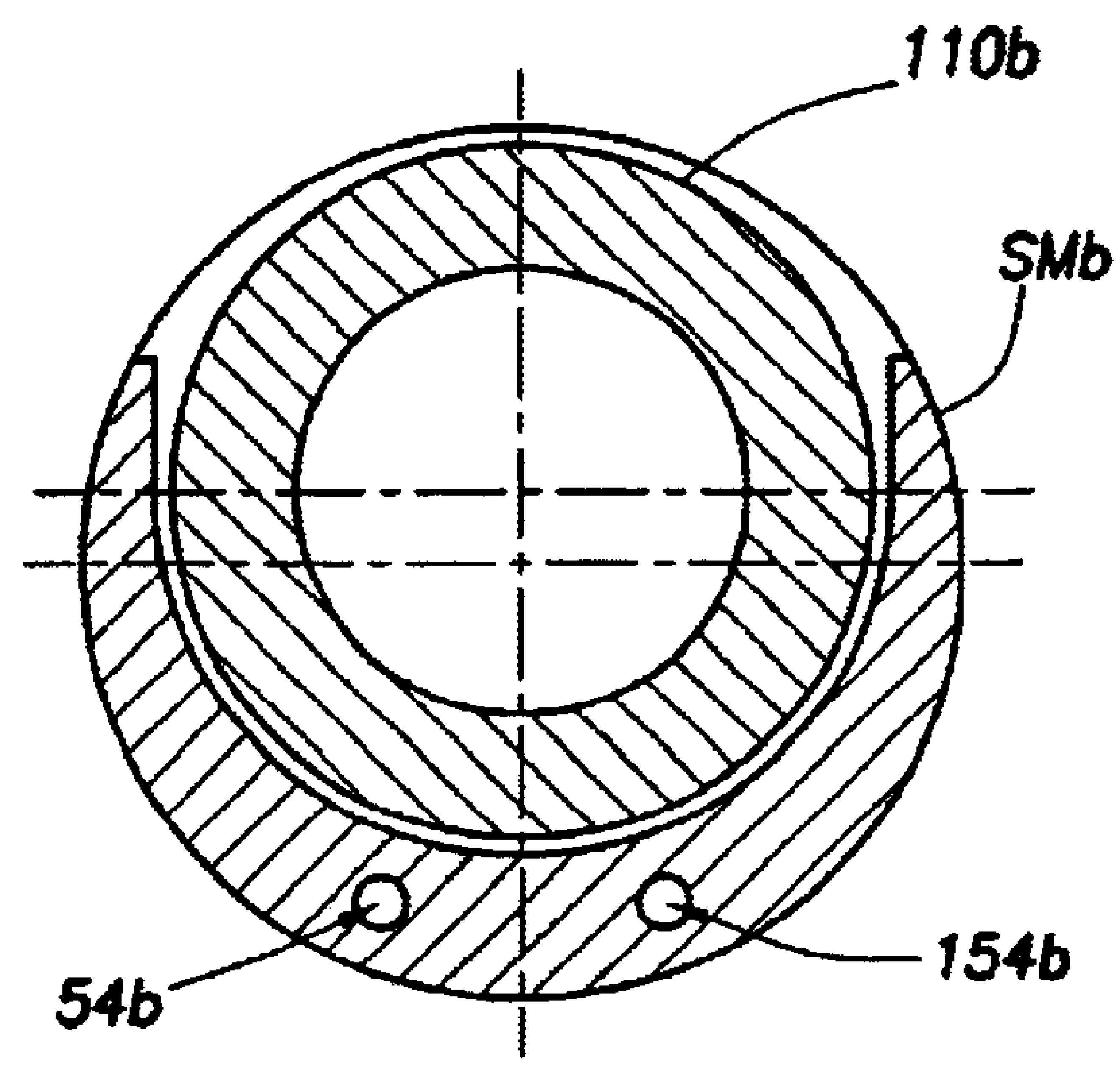


FIG.6B

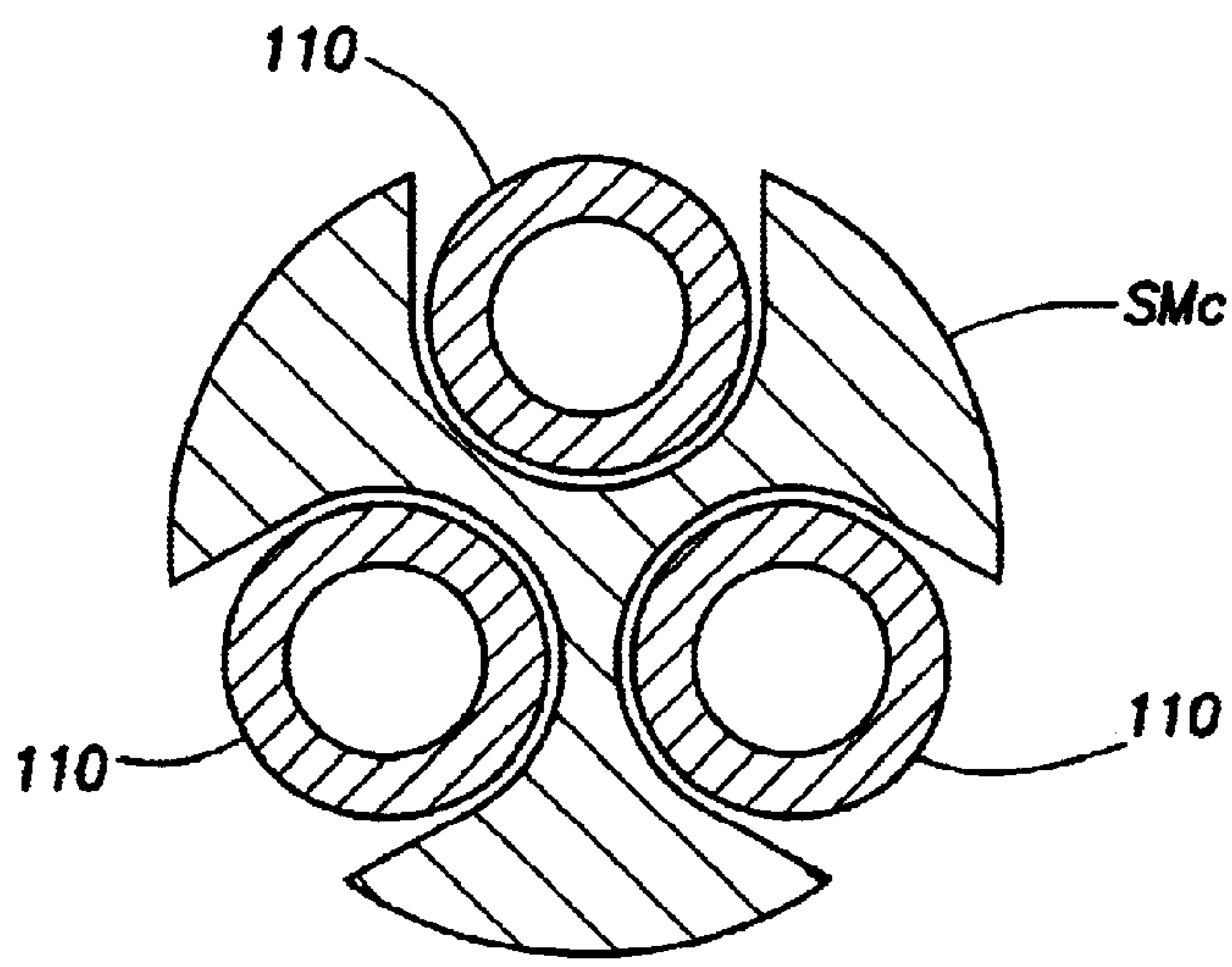


FIG.6C

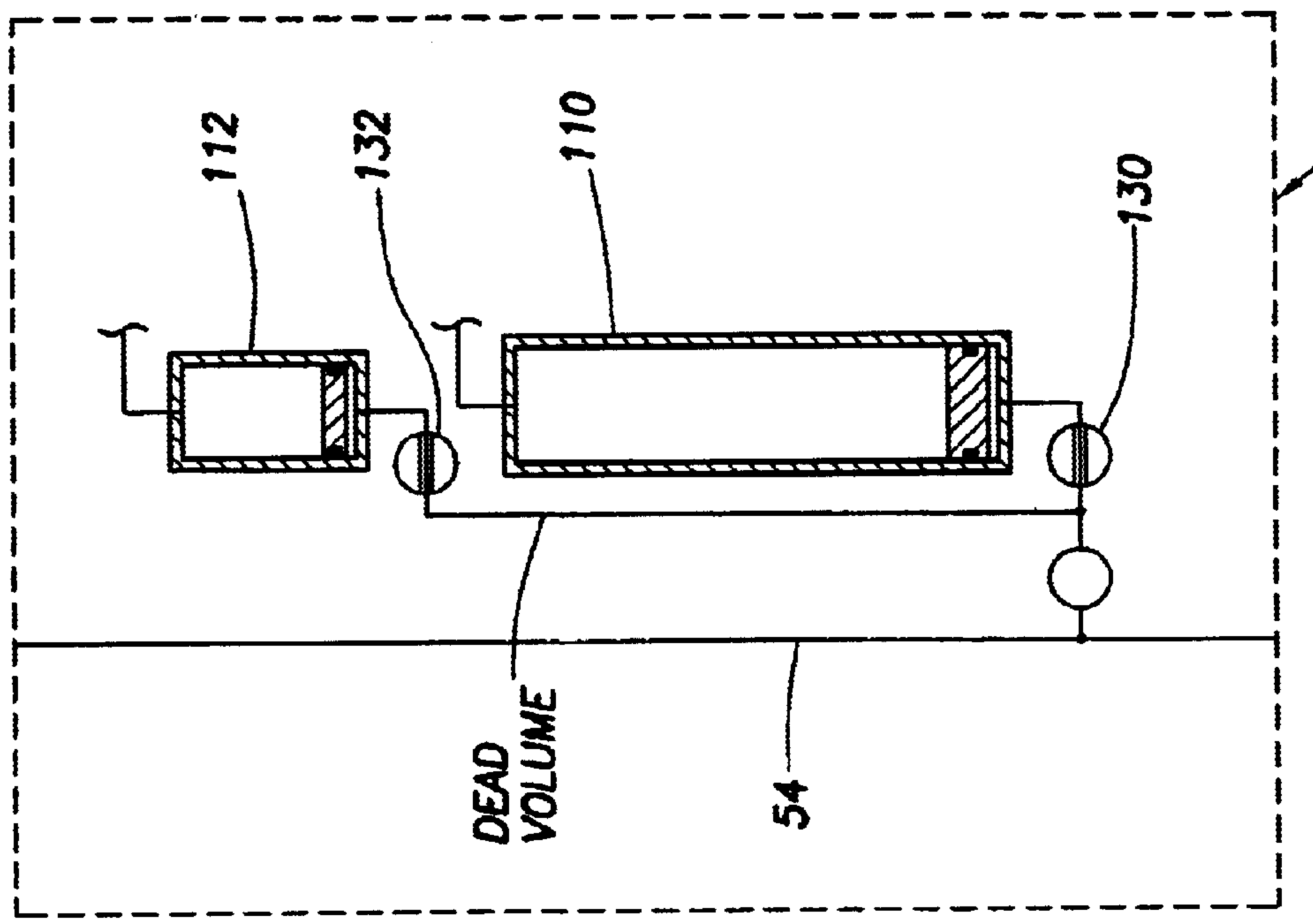

112
132
110
130
SM
DEAD VOLUME
54

FIG.8

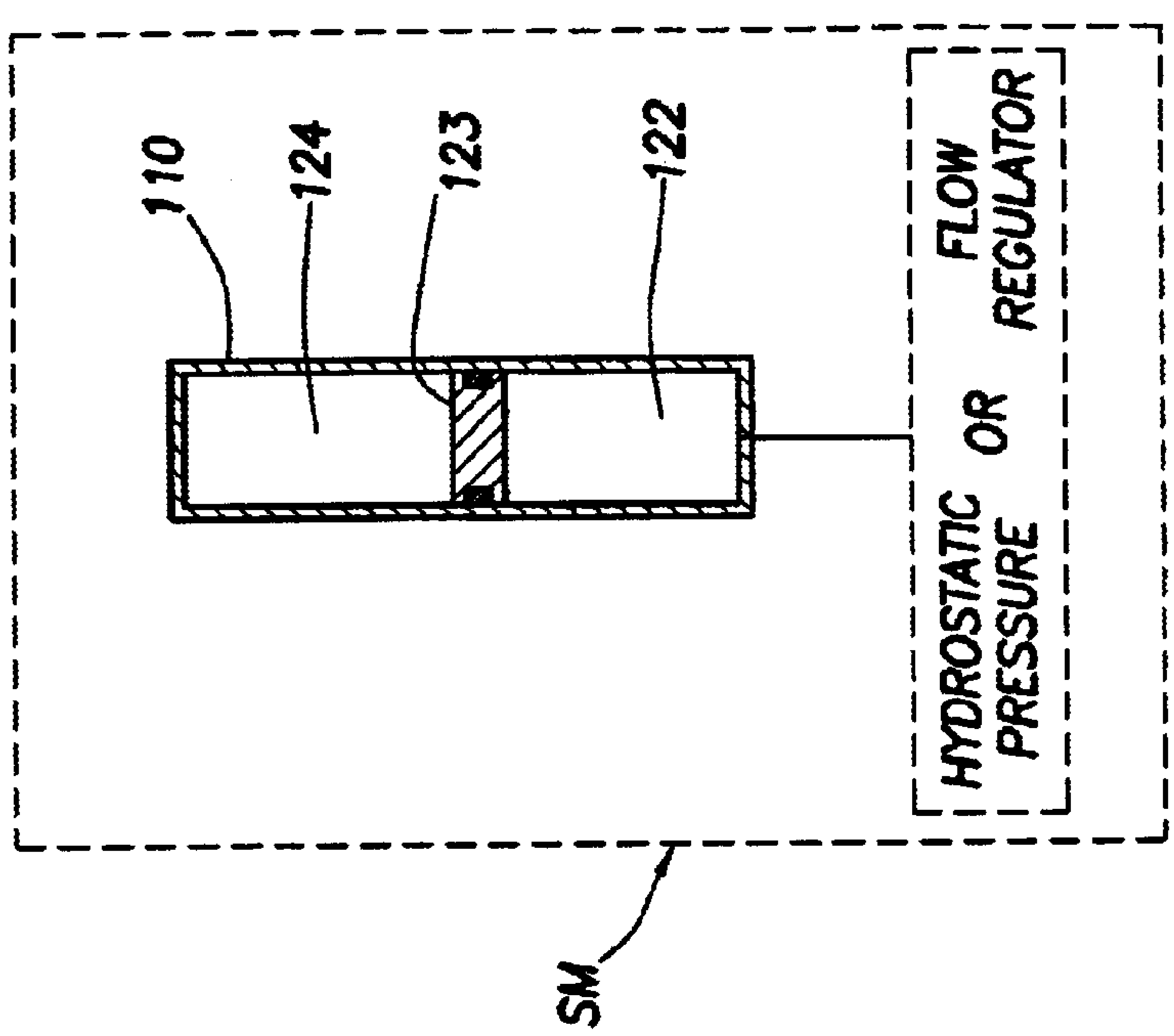

110
124
123
122
FLOW REGULATOR
OR
HYDROSTATIC PRESSURE
SM

FIG.7

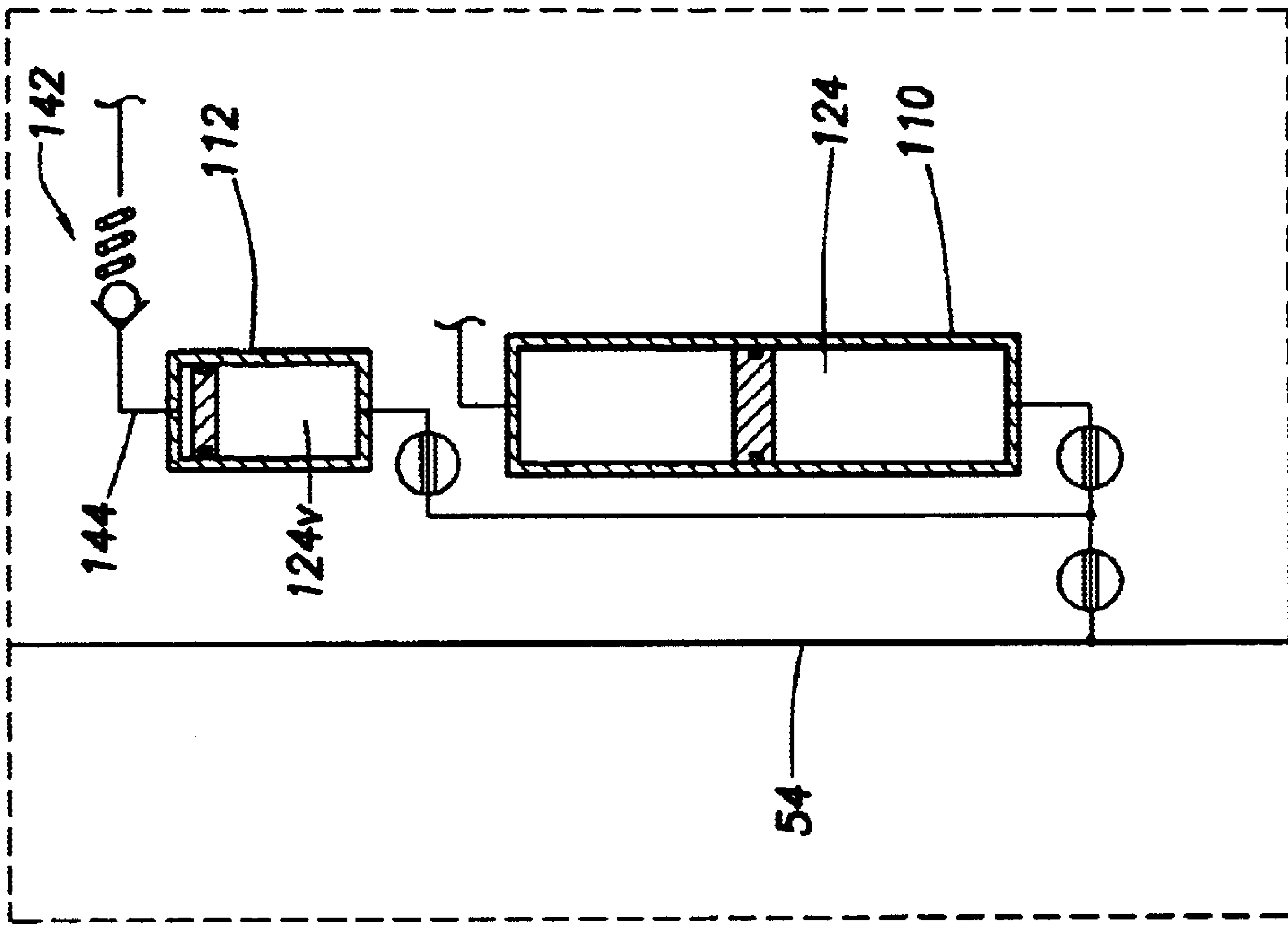


FIG.9B

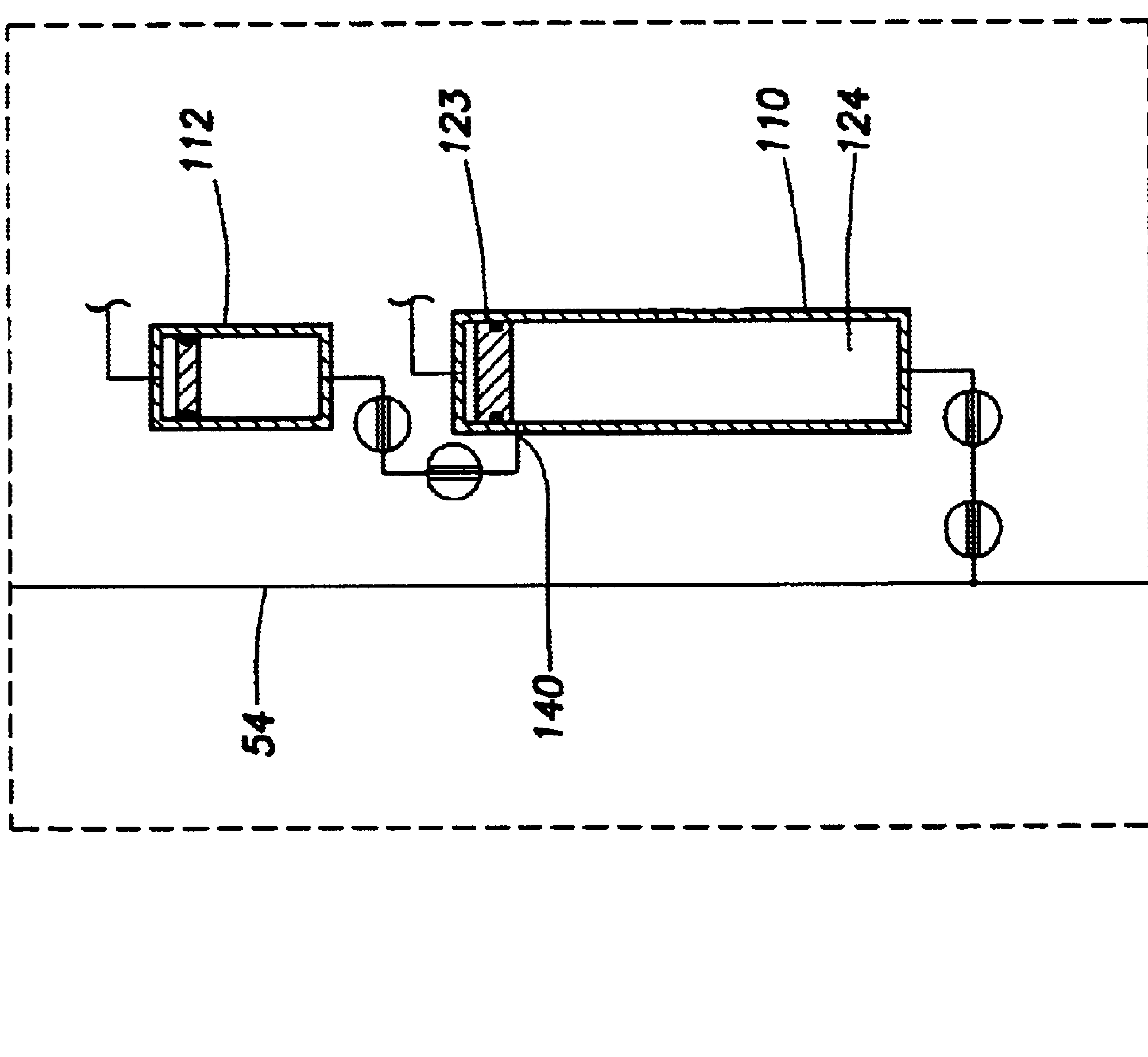


FIG.9A

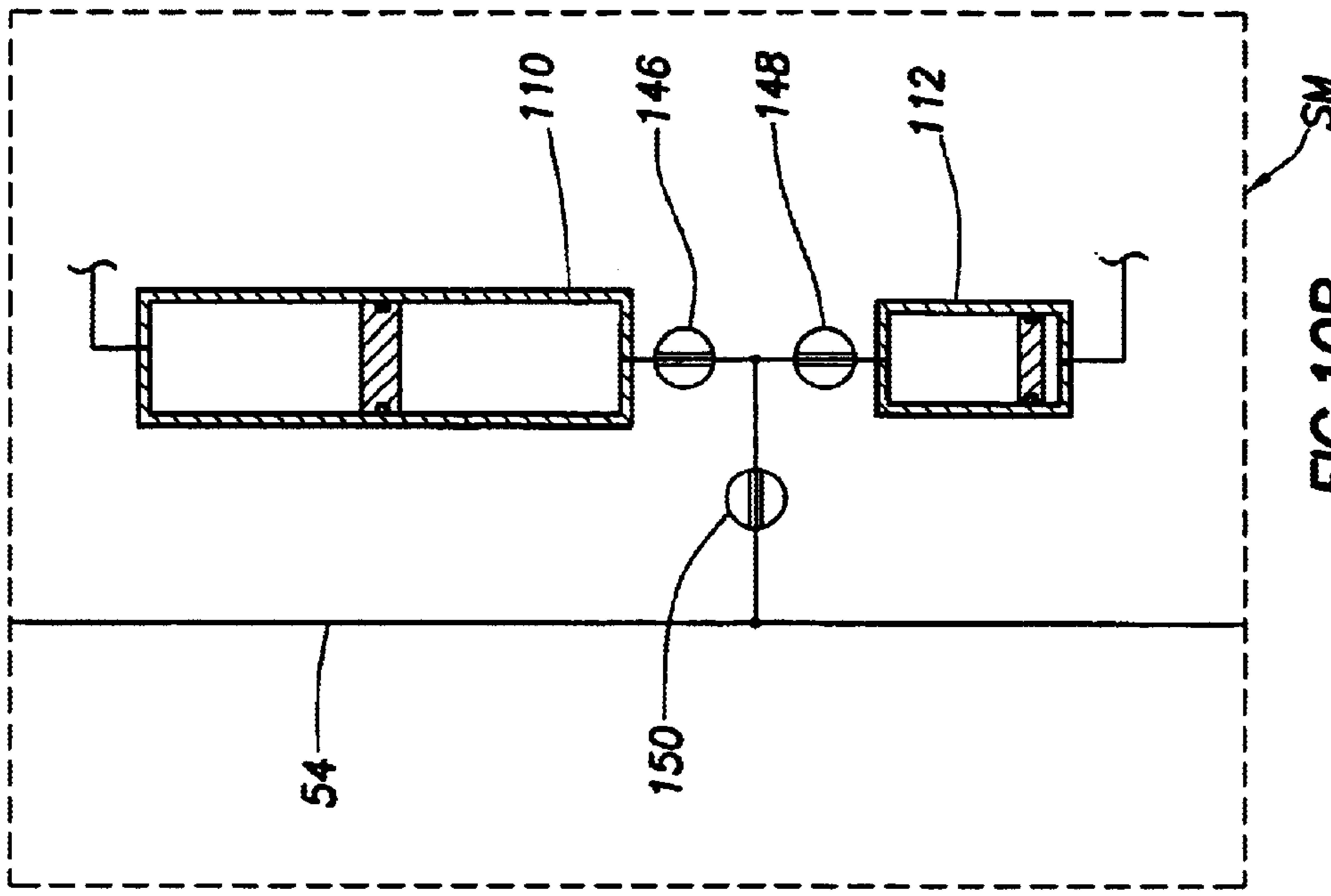


FIG. 10B

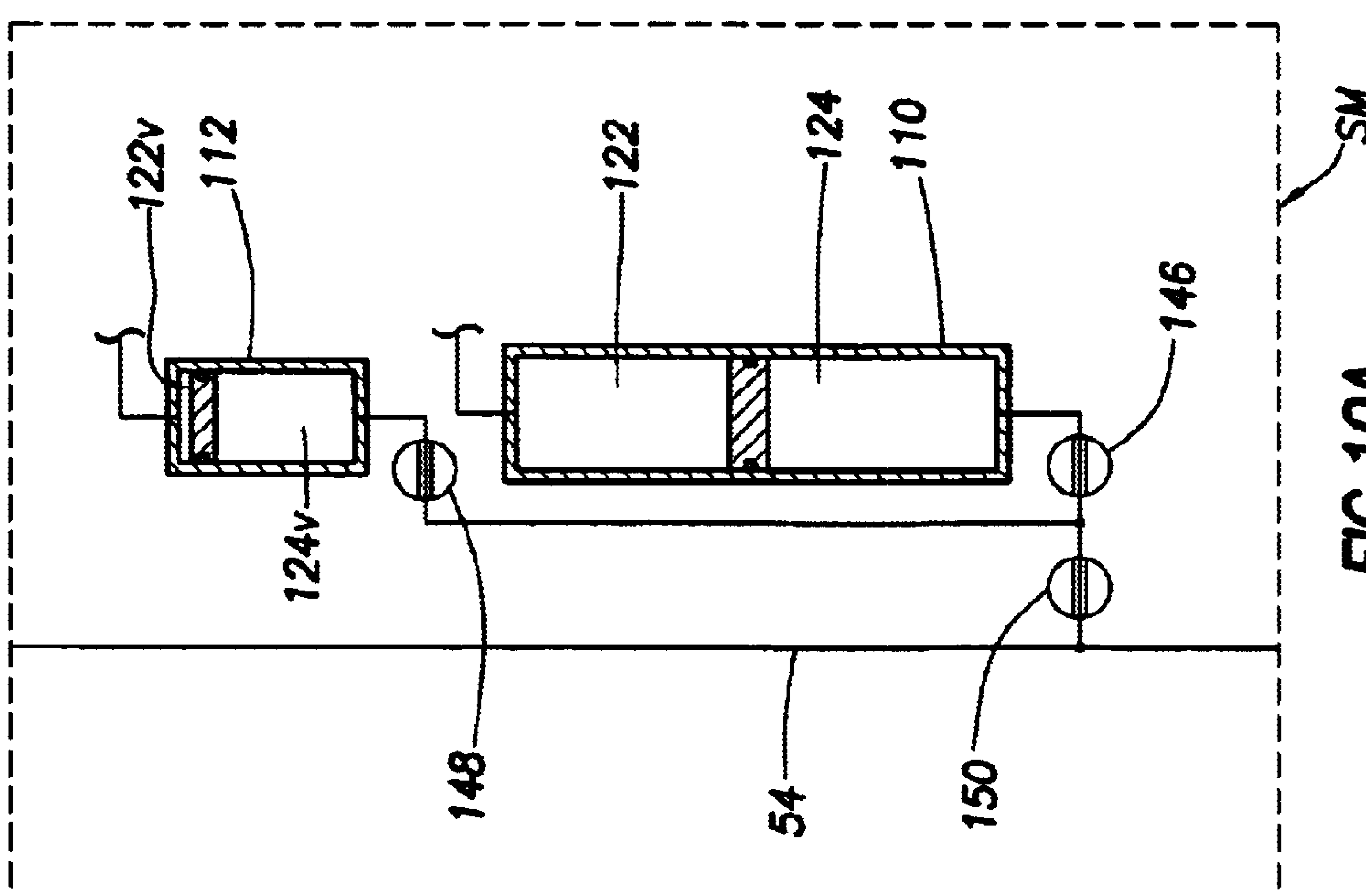


FIG. 10A

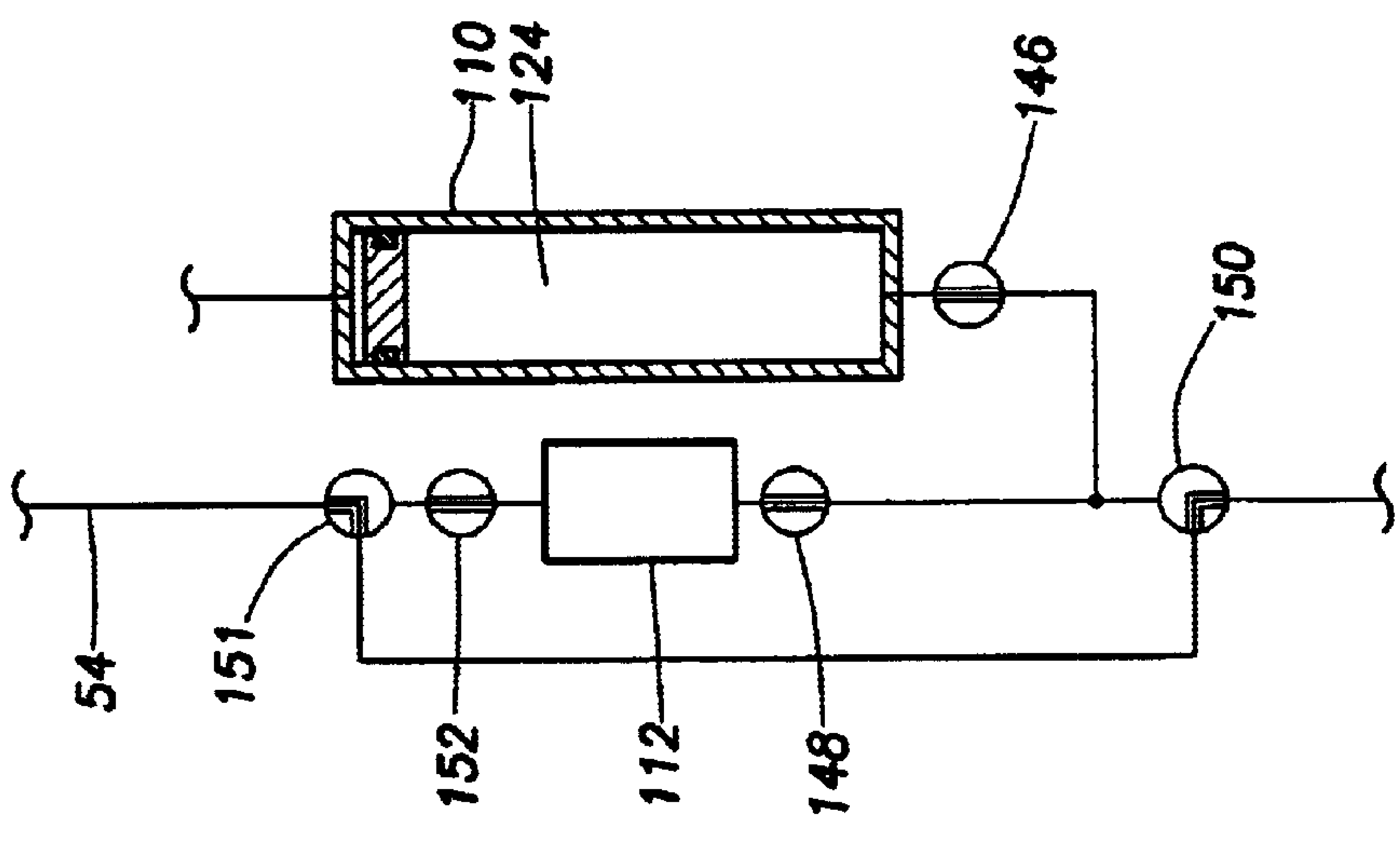


FIG.11C

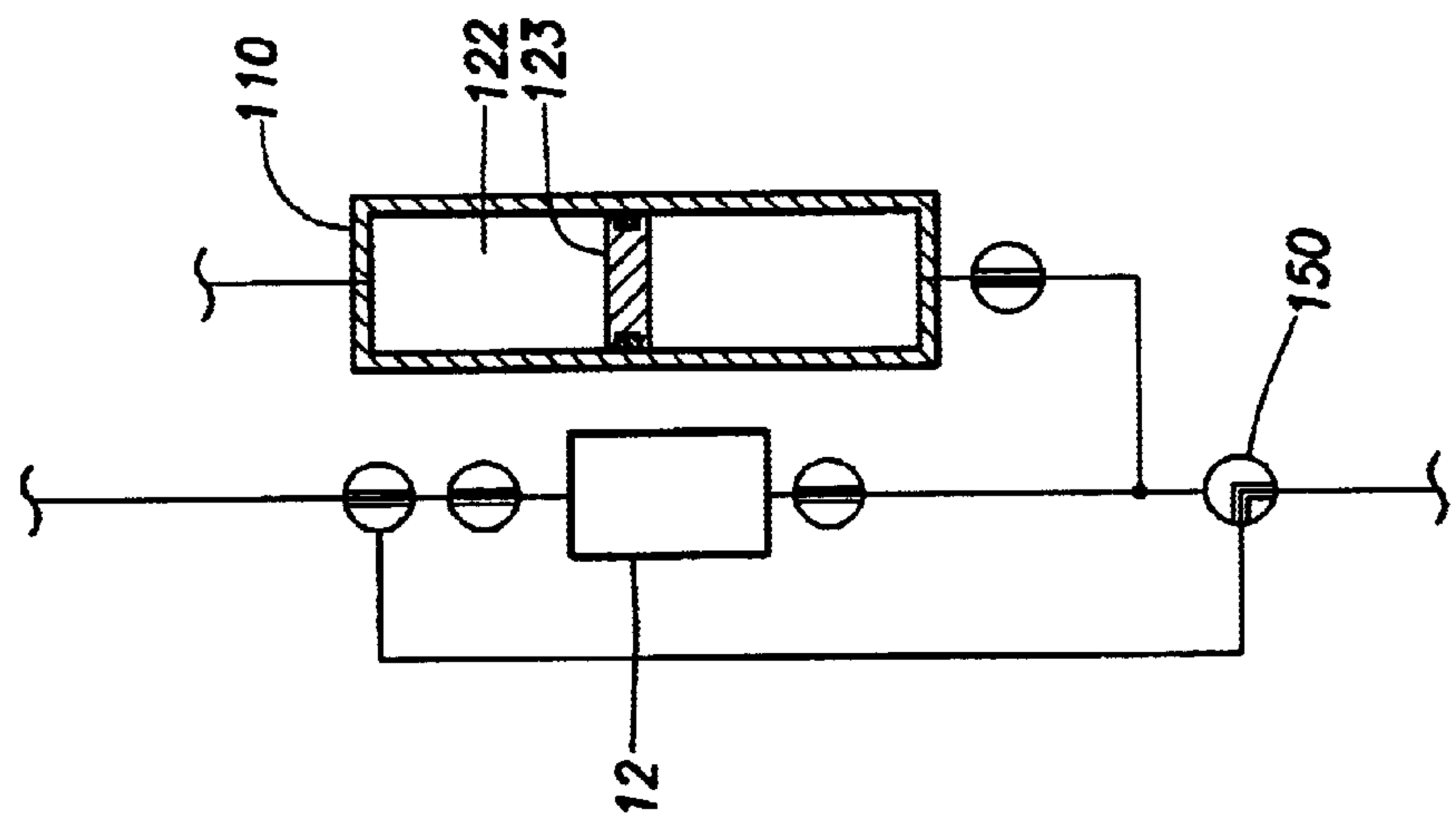


FIG.11B

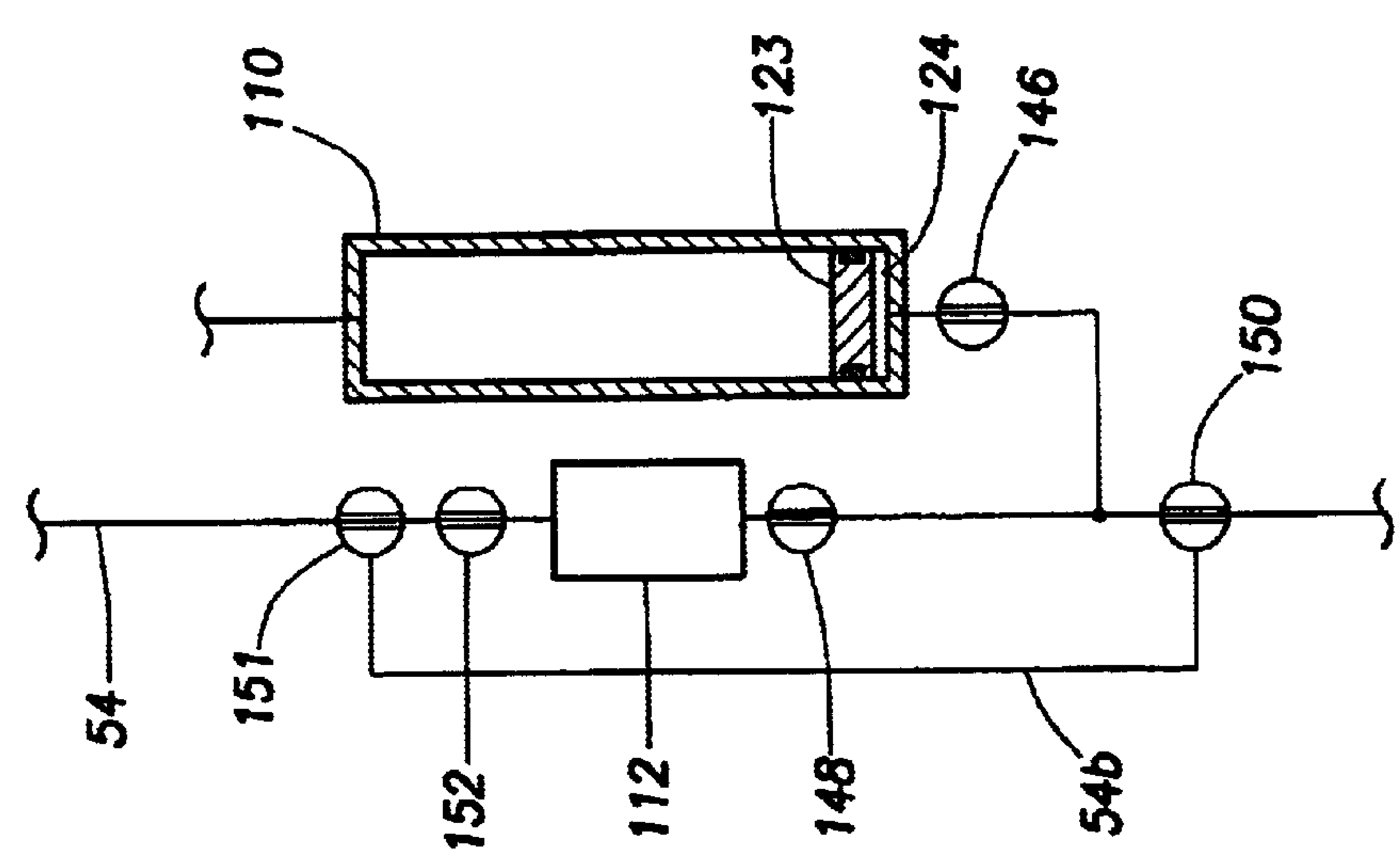


FIG.11A

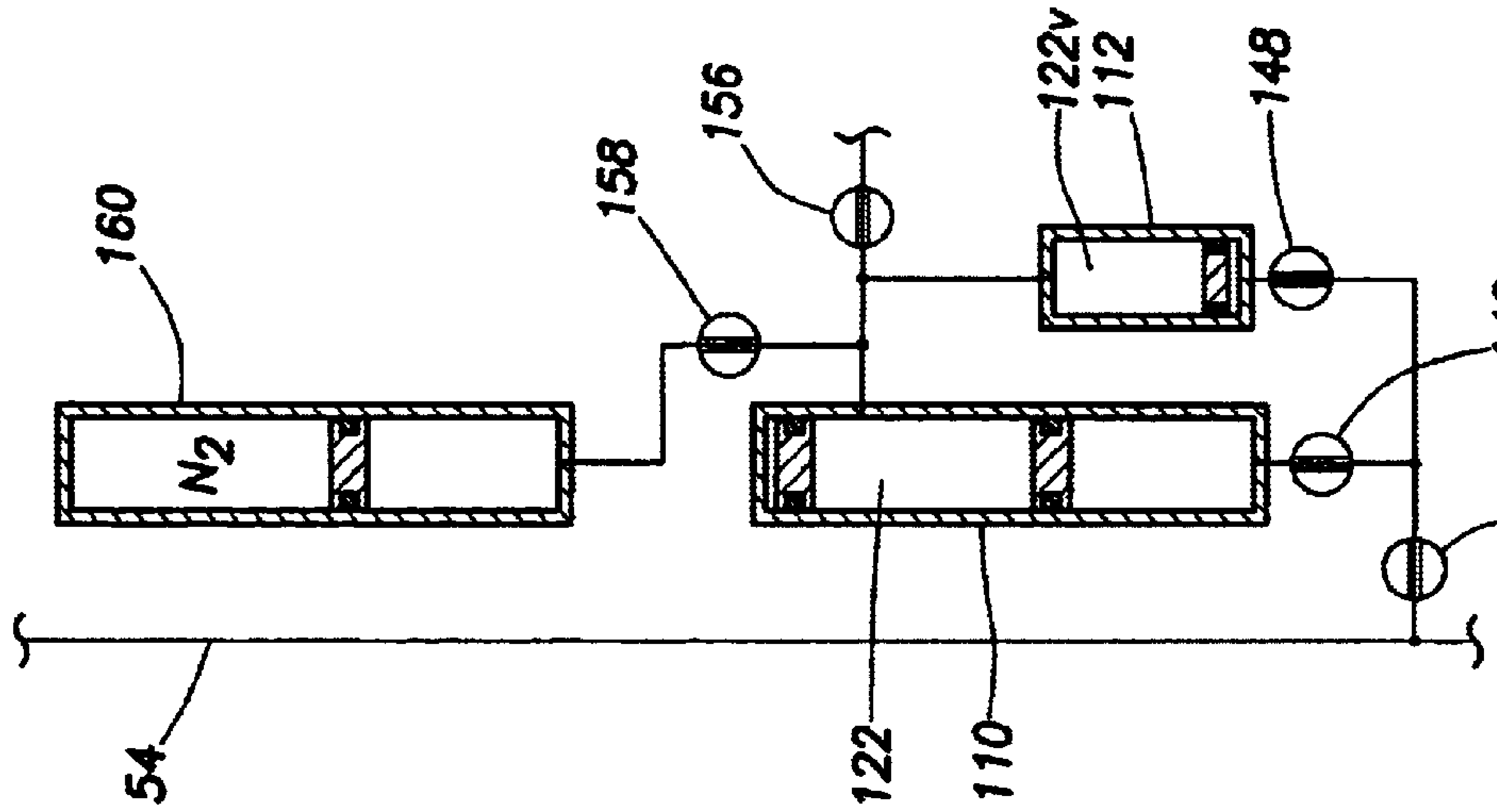

160
158
156
122v
112
148
146
150
N_2
54
122
110

FIG.15

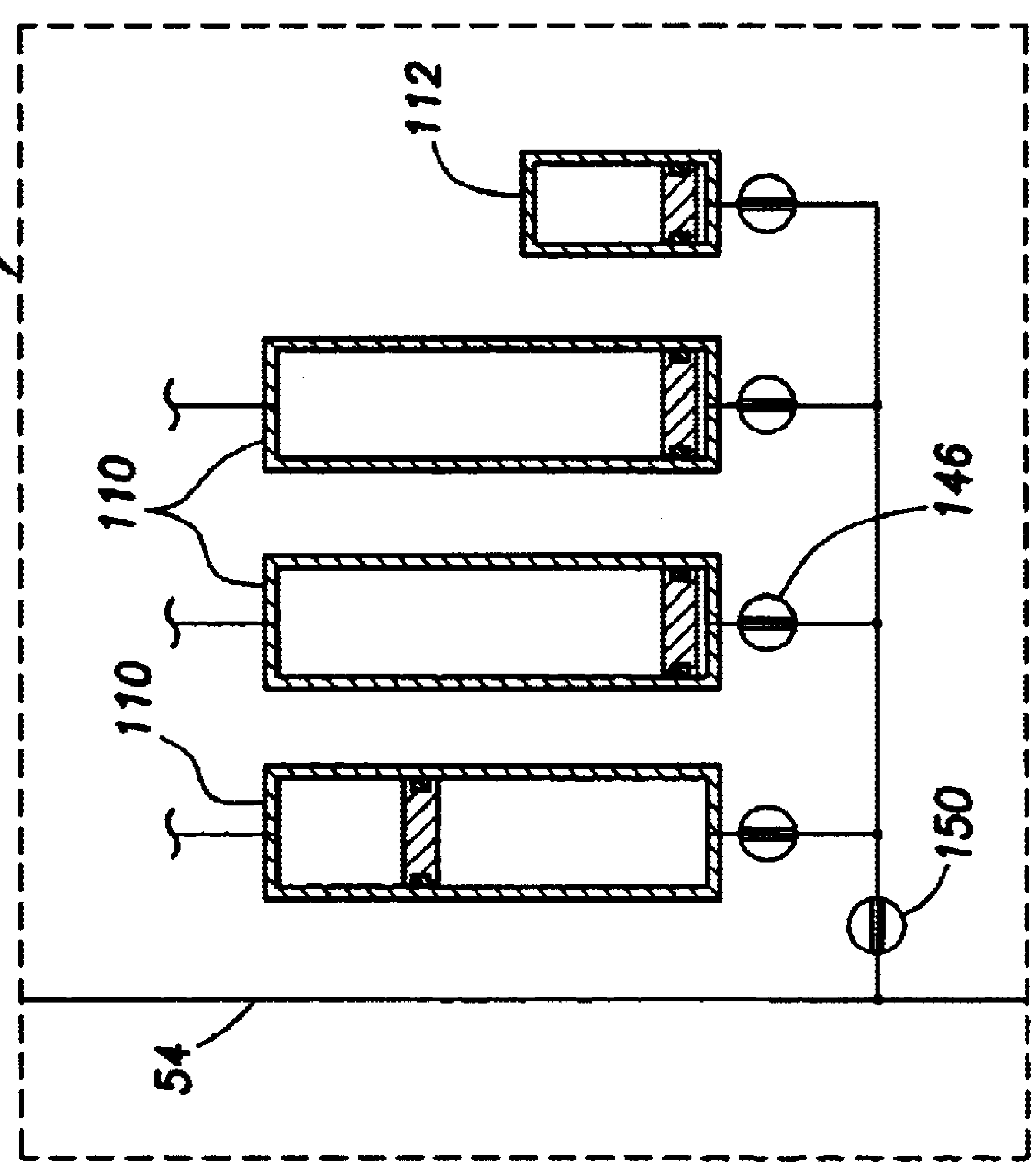

SM
112
110
110
146
150
54

FIG.12

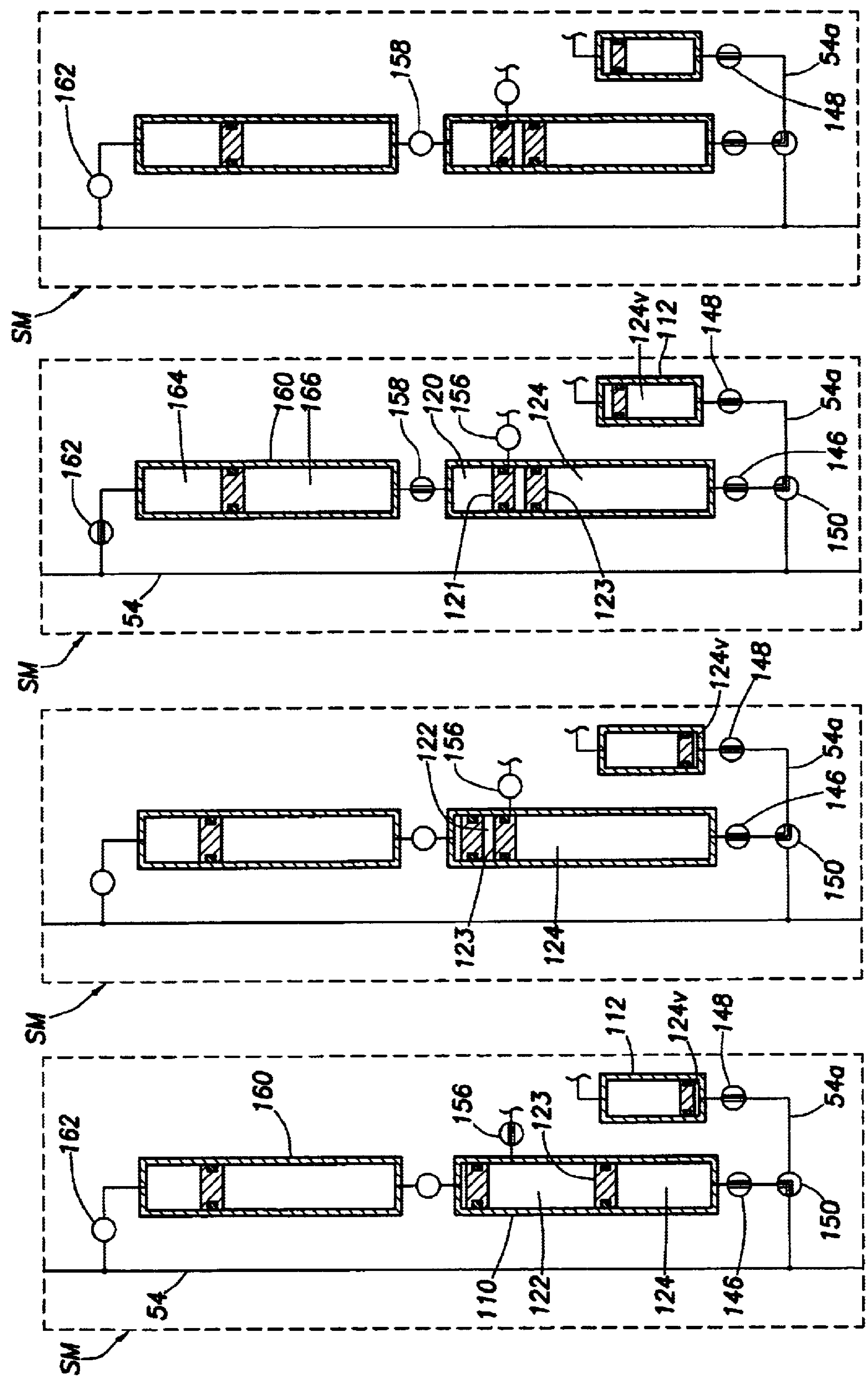


FIG. 13A
FIG. 13B
FIG. 13C
FIG. 13D

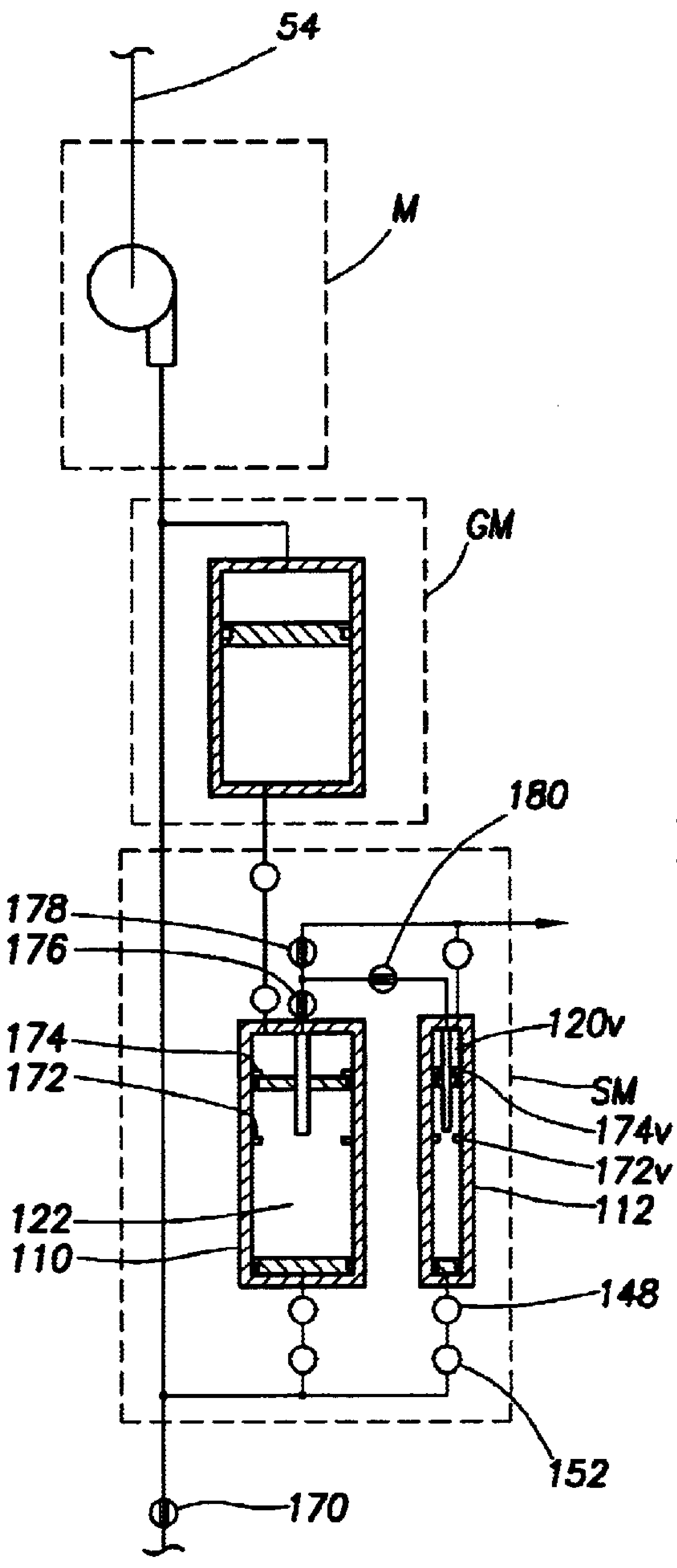


FIG. 14A

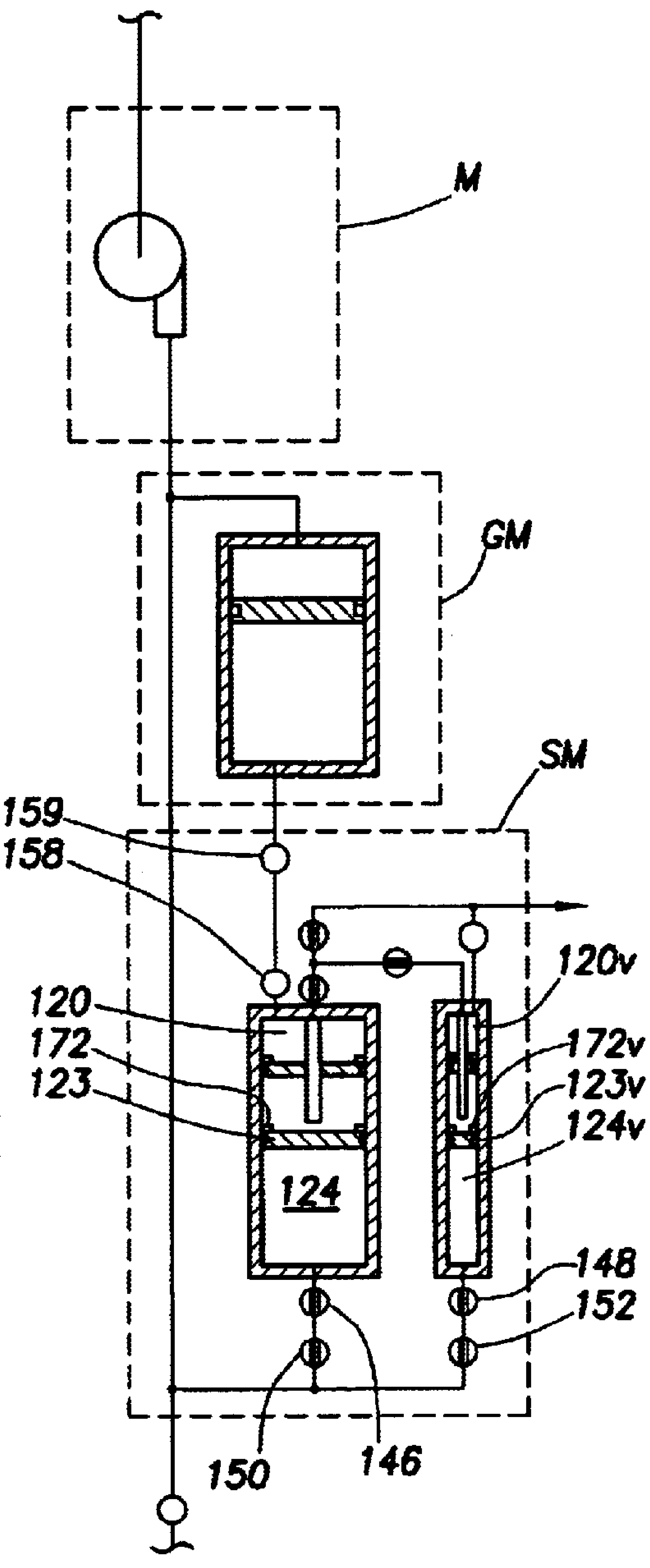


FIG. 14B

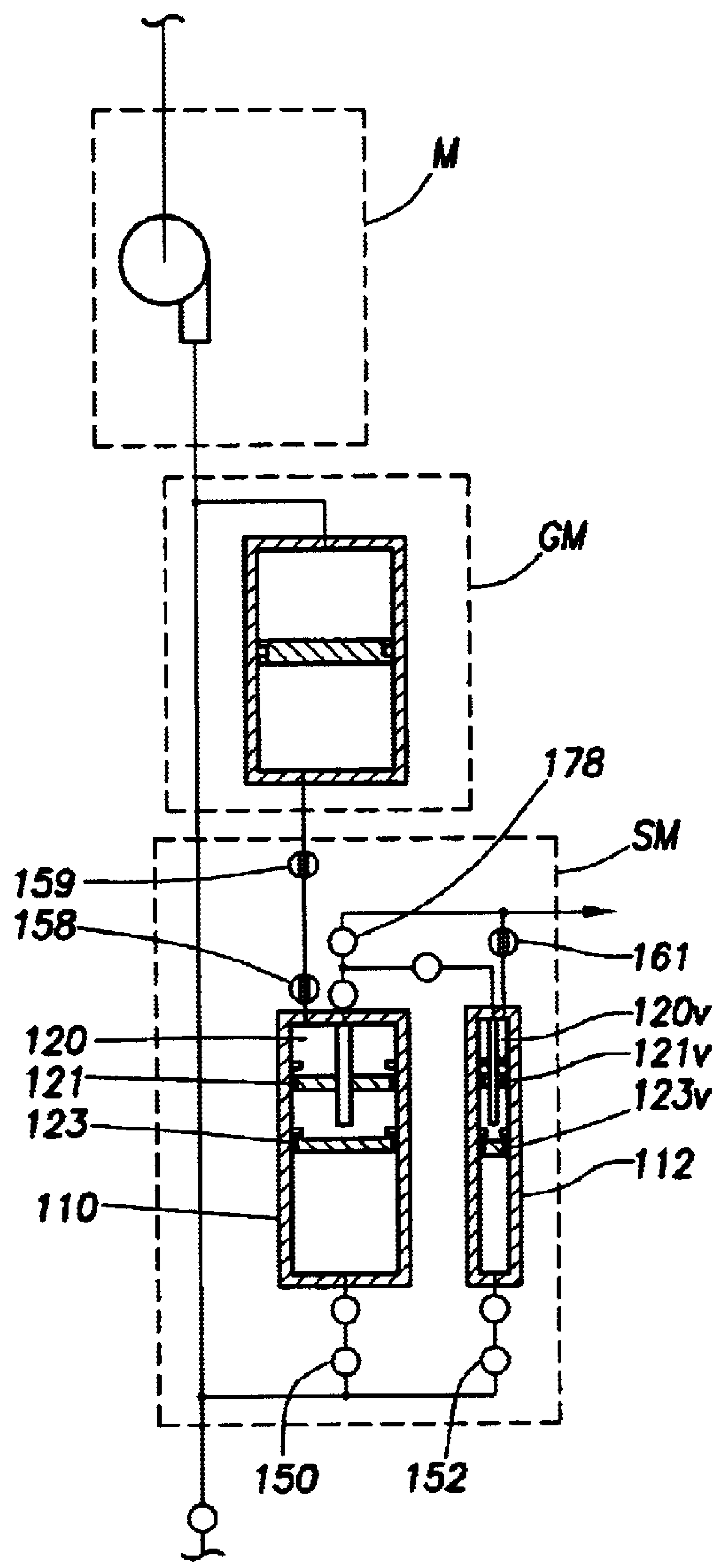


FIG. 14C

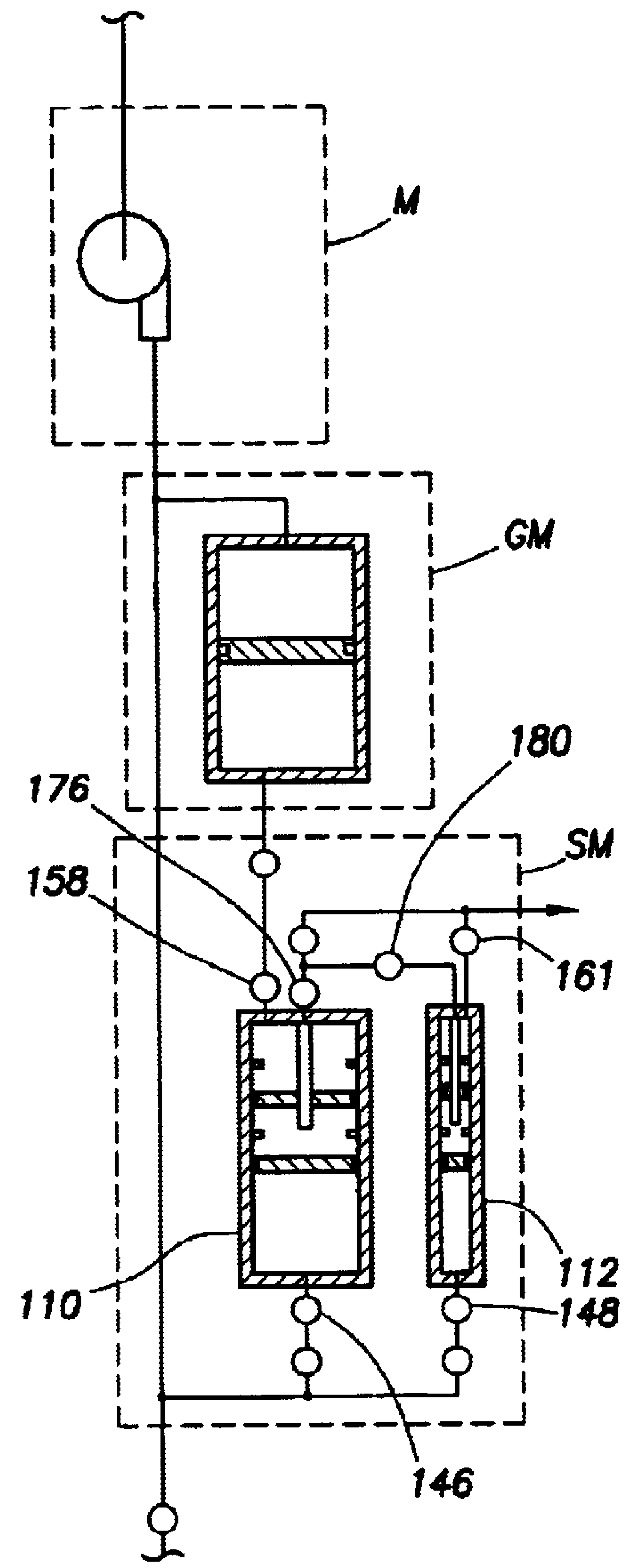


FIG. 14D

FORMATION FLUID SAMPLING APPARATUS AND METHOD

CROSS-REFERENCE TO RELATED APPLICATION

This application is a U.S. Provisional Patent Application Serial No. 60/126,088 filed on Mar. 25, 1999.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to formation fluid sampling, and more specifically to an improved reservoir fluid sampling module, the purpose of which is to bring high quality reservoir fluid samples to the surface for analysis.

2. The Related Art

The desirability of taking downhole formation fluid samples for chemical and physical analysis has long been recognized by oil companies, and such sampling has been performed by the assignee of the present invention, Schlumberger, for many years. Samples of formation fluid, also known as reservoir fluid, are typically collected as early as possible in the life of a reservoir for analysis at the surface and, more particularly, in specialized laboratories. The information that such analysis provides is vital in the planning and development of hydrocarbon reservoirs, as well as in the assessment of a reservoir's capacity and performance.

The process of wellbore sampling involves the lowering of a sampling tool, such as the MDT™ formation testing tool, owned and provided by Schlumberger, into the wellbore to collect a sample or multiple samples of formation fluid by engagement between a probe member of the sampling tool and the wall of the wellbore. The sampling tool creates a pressure differential across such engagement to induce formation fluid flow into one or more sample chambers within the sampling tool. This and similar processes are described in U.S. Pat. Nos. 4,860,581; 4,936,139 (both assigned to Schlumberger); U.S. Pat. Nos. 5,303,775; 5,377,755 (both assigned to Western Atlas); and U.S. Pat. No. 5,934,374 (assigned to Halliburton).

The desirability of housing at least one, and often a plurality, of such sample chambers, with associated valving and flow line connections, within "sample modules" is also known, and has been utilized to particular advantage in Schlumberger's MDT tool. Schlumberger currently has several types of such sample modules and sample chambers, each of which provide certain advantages for certain conditions. None of these sample module/chamber combinations, however, exhibit all the characteristics of: permitting a gas charge behind the collected sample for better pressure management of the sample; being heatable up to 400° F. at internal pressures up to 25,000 psi to promote the sample fluid components to go back into solution; being sized and certified for transportation directly from the well site to the laboratory without a need to transfer the collected sample; and being equipped to serve as a storage vessel. Nor do known sample chambers/modules sufficiently minimize the dead volume during sampling to reduce contamination of the sample by a pre-filling fluid, such as water.

To address these shortcomings, it is a principal object of the present invention to provide an apparatus and method for bringing a high quality formation fluid sample to the surface for analysis.

It is a further object of the present invention to provide a sample chamber that is safely heatable to at least 400° F. at internal pressures up to 25,000 psi at the surface.

It is a further object of the present invention to provide a sample chamber that is able to be pressurized to maintain a sample in "single phase," meaning that as the sample cools down pressure must be maintained so that components such as gas and asphaltenes, which would normally separate out of the mixture during the pressure reduction caused by the cooling of the sample mixture, will remain in solution. Components that do not stay in solution by maintaining pressure while the sample cools, such as paraffins, can be recombined by applying heat to the chamber at the surface. It is a further object of the present invention to provide a sample chamber that is certified for transportation so that, if desired, the sample can be taken directly to a lab for analysis without the need for transferring the sample from the sample chamber at the wellsite.

It is a further object to provide a sample chamber that is adapted for use as a storage vessel, meaning the sample contents will not leak across the seals that contain the sample within the sample chamber.

It is a further object to provide a sample chamber having a volume that is adequate for proper PVT sampling, but not too large that the sample could not be transferred, if desired, into a separate transportable sample bottle, most of which are 600 cc or less in capacity.

It is a further object to provide an independent validation sample chamber, having a substantially smaller capacity than the sample chamber, that will be safer and easier to heat and recombine separated sample components on the surface for validating the quality of the sample at the well site.

SUMMARY OF THE INVENTION

The objects described above, as well as various other objects and advantages, are achieved by a sample module for use in a downhole tool to obtain fluid from a subsurface formation penetrated by a wellbore. The sample module includes a sample chamber carried by the module for collecting a sample of formation fluid obtained from the formation via the downhole tool, and a validation chamber carried by the module for collecting a substantially smaller sample of formation fluid compared to the sample chamber. The validation chamber is removable from the sample module at the surface without disturbing the sample chamber.

The sample chamber and the validation chamber may be placed in either parallel or serial fluid communication with a fluid flowline in the downhole tool such that the chambers may be filled either substantially simultaneously or consecutively as desired.

Preferably, the sample chamber is adapted for maintaining the sample stored therein in a single phase condition as the sample module is withdrawn with the downhole tool from the wellbore. The phrase "single phase" is used herein to mean that the pressure of the sample within a chamber is maintained or controlled to such an extent that sample constituents which are maintained in a solution through pressure only, such as gasses and asphaltenes, should not separate out of solution as the sample cools upon withdrawal from the wellbore. The sample may be reheated at the surface to recombine the constituents which have come out of solution due to cooling, such as paraffins. Alternatively, the validation chamber may also be adapted for maintaining the fluid sample stored therein in a single phase condition as the sample module is withdrawn from the wellbore.

It is also preferred that the sample chambers be capable of safely withstanding heating at the surface, following collection of samples and withdrawal of the sample module from the wellbore, to temperatures necessary to promote recombination of the sample components within the chambers that may have separated due to cooling upon withdrawal.

It is further preferred that the sample chamber be sufficiently equipped so as to be certified for transportation.

Still further, it is desirable that the sample chamber be adapted for storing the sample collected therein for an indefinite period without substantial degradation of the sample. One solution for achieving this goal is for the sample chamber to include metal-to-metal seals as the final shut-off seals for the sample collected therein.

In another aspect, the present invention provides an improved sample chamber for use in a downhole tool to obtain fluid from a subsurface formation penetrated by a wellbore. The improved sample chamber includes a substantially cylindrical body capable of safely withstanding heating at the surface, following collection of a formation fluid sample via the downhole tool and withdrawal of the sample chamber from the wellbore, to temperatures necessary to promote recombination of the sample components within the chambers. Additionally, the body is sufficiently equipped so as to be certified for transportation. At least one floating piston is slidably positioned within the body so as to define a fluid collection cavity and a pressurization cavity, whereby the pressurization cavity may be charged to control the pressure of the sample collected in the collection cavity. A second such piston may be provided to create a third cavity wherein a buffer fluid may be utilized during sample collection. Metal-to-metal seals act as the final shut-off seals for the sample collected in the collection cavity of the body.

In another aspect, the present invention provides an apparatus for obtaining fluid from a subsurface formation penetrated by a wellbore. The apparatus includes a probe assembly for establishing fluid communication between the apparatus and the formation when the apparatus is positioned in the wellbore, and a pump assembly for drawing fluid from the formation into the apparatus. A sample chamber is provided for collecting a sample of the formation fluid drawn from the formation by the pumping assembly, and a validation chamber is provided for collecting a substantially smaller sample of the formation fluid than the sample chamber. The validation chamber is removable from the apparatus at the surface without disturbing the sample chamber or its contents.

It is preferred that the sample chamber be adapted for maintaining the sample stored therein in a single phase condition as the apparatus is withdrawn from the wellbore. In this regard, the sample chamber may include at least one floating piston slidably positioned within the sample chamber so as to define a fluid collection cavity and a pressurization cavity. A flow line in the apparatus establishes fluid communication between the probe assembly, the pump assembly, and the fluid collection cavity of the sample chamber. A pressurization system in the apparatus charges the pressurization cavity to control the pressure of the collected sample fluid within the collection cavity via the floating piston. The pressurization system preferably includes a valve positioned for fluid communication with the pressurization cavity of the sample chamber, the valve being movable between positions closing the pressurization cavity and opening the pressurization cavity to a source of fluid at a greater pressure than the pressure of the formation fluid delivered to the collection cavity.

The pressurization system controls the pressure of the collected sample fluid within the collection cavity during either collection of the sample from the formation, or retrieval of the apparatus from the wellbore to the surface, or both. For the former purpose, the source of fluid at a greater pressure than the pressure of the collected sample fluid may be wellbore fluid. For the latter purpose, the source of fluid at a greater pressure than the pressure of the collected sample fluid may be a source of inert gas, such as Nitrogen, carried by the apparatus.

The apparatus may be a wireline-conveyed formation testing tool, but is not necessarily so limited.

In another aspect, the present invention contemplates a method for obtaining fluid from a subsurface formation penetrated by a wellbore, and includes the steps of positioning an apparatus within the wellbore, establishing fluid communication between the apparatus and the formation, and inducing movement of fluid from the formation into the apparatus. A sample of the formation fluid moved into the apparatus is delivered to a sample chamber for collection therein, and a substantially smaller sample of the formation fluid moved into the apparatus is delivered to a validation chamber for collection therein. This permits the smaller sample to be evaluated independently of the sample stored in the sample chamber following withdrawal of the apparatus from the wellbore to recover the collected samples.

BRIEF DESCRIPTION OF THE DRAWINGS

The manner in which the present invention attains the above recited features, advantages, and objects can be understood in detail by reference to the preferred embodiments thereof which are illustrated in the accompanying drawings.

It should be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

In the drawings:

FIGS. **1** and **2** are schematic illustrations of a prior art formation testing apparatus and its various modular components;

FIG. **3** is a simplified schematic illustration of a sample module for use in a formation tester in accordance with the present invention;

FIG. **3**A is a cross-sectional illustration of a sample chamber in accordance with the present invention;

FIG. **4** is a schematic illustration of a basic gas charging system contained in a sample chamber according to the present invention;

FIGS. **5**A and **5**B are schematic illustrations of two alternative gas charging systems contained in a sample module according to the present invention;

FIGS. **6**A–C are cross-sectional illustrations of various alternative embodiments of sample chamber/sample module configurations;

FIG. **7** is a schematic illustration of alternative means for charging a buffer fluid in a sample chamber according to the present invention;

FIG. **8** is a schematic illustration of the concept of dead volume, which is desirable to minimize;

FIGS. **9**A and **9**B are schematic illustrations of two alternative arrangements for sequentially filling a sample chamber and validation chamber according to the present invention;

FIGS. **10**A and **10**B are schematic illustrations of two alternative arrangements for filling a sample chamber and validation chamber in parallel according to the present invention;

FIGS. **11**A–C are schematic illustrations of three alternative arrangements for sequentially filling a sample chamber and validation chamber by flowing formation fluid through the validation chamber according to the present invention;

FIG. **12** is a schematic illustration of multiple sample chambers arranged for filling in parallel with a validation chamber according to the present invention;

FIGS. **13**A–D are schematic illustrations of the of steps involved in filling a sample chamber, shutting in the sample chamber, using a separate gas charging chamber for extracting a portion of the sample from the sample chamber to the validation chamber, and shutting in both the sample and validation chambers; and

FIGS. **14**A–D are schematic illustrations of the steps involved in flushing formation fluid through a sample module flow line, collecting in parallel samples of the formation fluid in a sample chamber and validation chamber of the sample module, shutting in the collected samples and charging them with gas via a buffer fluid in both chambers, and maintaining the pressure of the collected samples during withdrawal of the sample module to the surface.

FIG. **15** is a schematic illustration of a sample module incorporating a gas charging chamber that pressurizes buffer fluid in sample and validation chambers independently of a fluid flow line in the sample module.

DETAILED DESCRIPTION OF THE INVENTION

Turning first to prior art FIGS. **1** and **2**, a preferred apparatus with which the present invention may be used to advantage is seen. The apparatus A of FIGS. **1** and **2** is preferably of modular construction although a unitary tool is also useful. The apparatus A is a down hole tool which can be lowered into the well bore (not shown) by a wire line (not shown) for the purpose of conducting formation property tests. The wire line connections to the tool as well as power supply and communications-related electronics are not illustrated for the purpose of clarity. The power and communication lines which extend throughout the length of the tool are generally shown at **8**. These power supply and communication components are known to those skilled in the art and have been in commercial use in the past. This type of control equipment would normally be installed at the uppermost end of the tool adjacent the wire line connection to the tool with electrical lines running through the tool to the various components.

As shown in FIG. **1**, the apparatus A has a hydraulic power module C, a packer module P, and a probe module E. Probe module E is shown with one probe assembly **10** which may be used for permeability tests or fluid sampling. When using the tool to determine anisotropic permeability and the vertical reservoir structure according to known techniques, a multiprobe module F can be added to probe module E, as shown in FIG. **1**. Multiprobe module F has horizontal probe assembly **12** and sink probe assembly **14**.

The hydraulic power module C includes pump **16**, reservoir **18**, and motor **20** to control the operation of the pump. Low oil switch **22** also forms part of the control system and is used in regulating the operation of pump **16**. It should be noted that the operation of the pump can be controlled by pneumatic or hydraulic means.

Hydraulic fluid line **24** is connected to the discharge of pump **16** and runs through hydraulic power module C and into adjacent modules for use as a hydraulic power source. In the embodiment shown in FIG. **1**, hydraulic fluid line **24** extends through hydraulic power module C into packer

module P via probe module E and/or F depending upon which configuration is used. The hydraulic loop is closed by virtue of hydraulic fluid return line **26**, which in FIG. **1** extends from probe module E back to hydraulic power module C where it terminates at reservoir **18**.

The pump-out module M, seen in FIG. **2**, can be used to dispose of unwanted samples by virtue of pumping fluid through flow line **54** into the borehole, or may be used to pump fluids from the borehole into the flow line **54** to inflate straddle packers **28** and **30**. Furthermore, pump-out module M may be used to draw formation fluid from the wellbore via probe module E or F, and then pump the formation fluid into sample chamber module S against a buffer fluid therein. This process will be described further below.

Bi-directional piston pump **92**, energized by hydraulic fluid from pump **91**, can be aligned to draw from flow line **54** and dispose of the unwanted sample though flow line **95** or may be aligned to pump fluid from the borehole (via flow line **95**) to flow line **54**. The pump out module M has the necessary control devices to regulate pump **92** and align fluid line **54** with fluid line **95** to accomplish the pump out procedure. It should be noted here that pump **92** can be used to pump samples into sample chamber module(s) S, including overpressuring such samples as desired, as well as to pump samples out of sample chamber module(s) S using pump-out module M. Pump-out module M may also be used to accomplish constant pressure or constant rate injection if necessary. With sufficient power, the pump out module may be used to inject fluid at high enough rates so as to enable creation of microfractures for stress measurement of the formation.

Alternatively, straddle packers **28** and **30** shown in FIG. **1** can be inflated and deflated with hydraulic fluid from pump **16**. As can be readily seen, selective actuation of the pump-out module M to activate pump **92** combined with selective operation of control valve **96** and inflation and deflation valves I, can result in selective inflation or deflation of packers **28** and **30**. Packers **28** and **30** are mounted to outer periphery **32** of the apparatus A, and are preferably constructed of a resilient material compatible with wellbore fluids and temperatures. Packers **28** and **30** have a cavity therein. When pump **92** is operational and inflation valves I are properly set, fluid from flow line **54** passes through inflation/deflation means I, and through flow line **38** to packers **28** and **30**.

As also shown in FIG. **1**, the probe module E has probe assembly **10** which is selectively movable with respect to the apparatus A. Movement of probe assembly **10** is initiated by operation of probe actuator **40**, which aligns hydraulic flow lines **24** and **26** with flow lines **42** and **44**. Probe **46** is mounted to a frame **48**, which is movable with respect to apparatus A, and probe **46** is movable with respect to frame **48**. These relative movements are initiated by controller **40** by directing fluid from flow lines **24** and **26** selectively into flow lines **42** and **44** with the result being that the frame **48** is initially outwardly displaced into contact with the borehole wall (not shown). The extension of frame **48** helps to steady the tool during use and brings probe **46** adjacent the borehole wall. Since one objective is to obtain an accurate reading of pressure in the formation, which pressure is reflected at the probe **46**, it is desirable to further insert probe **46** through the built up mudcake and into contact with the formation. Thus, alignment of hydraulic flow line **24** with flow line **44** results in relative displacement of probe **46** into the formation by relative motion of probe **46** with respect to frame **48**. The operation of probes **12** and **14** is similar to that of probe **10**, and will not be described separately.

Having inflated packers **28** and **30** and/or set probe **46** and/or probes **12** and **14**, the fluid withdrawal testing of the formation can begin. Sample flow line **54** extends from probe **46** in probe module E down to the outer periphery **32** at a point between packers **28** and **30** through adjacent modules and into the sample modules S. Vertical probe **46** and sink probes **12** and **14** thus allow entry of formation fluids into sample flow line **54** via one or more of a resistivity measurement cell **56**, a pressure measurement device **58**, and a pretest mechanism **59**, according to the desired configuration. When using module E, or multiple modules E and F, isolation valve **62** is mounted downstream of resistivity sensor **56**. In the closed position, isolation valve **62** limits the internal flow line volume, improving the accuracy of dynamic measurements made by pressure gauge **58**. After initial pressure tests are made, isolation valve **62** can be opened to allow flow into other modules.

When taking initial samples, there is a high prospect that the formation fluid initially obtained is contaminated with mud cake and filtrate. It is desirable to purge such contaminants from the sample flow stream prior to collecting sample(s). Accordingly, the pump-out module M is used to initially purge from the apparatus A specimens of formation fluid taken through inlet **64** of straddle packers **28**, **30**, or vertical probe **46**, or sink probes **12** or **14** into flow line **54**.

Fluid analysis module D included optical fluid analyzer **99** which is particularly suited for the purpose of indicating where the fluid in flow line **54** is acceptable for collecting a high quality sample. Optical fluid analyzer **99** is equipped to discriminate between various oils, gas, and water. U.S. Pat. Nos. 4,994,671; 5,166,747; 5,939,717; and 5,956,132, as well as other known patents, all assigned to Schlumberger, describe analyzer **99** in detail, and such description will not be repeated herein, but is incorporated by reference in its entirety.

While flushing out the contaminants from apparatus A, formation fluid can continue to flow through sample flow line **54** which extends through adjacent modules such as precision pressure module B, fluid analysis module D, pump out module M (FIG. **2**), flow control module N, and any number of sample chamber modules S that may be attached. Those skilled in the art will appreciate that by having a sample flow line **54** running the length of various modules, multiple sample chamber modules S can be stacked without necessarily increasing the overall diameter of the tool. Alternatively, as explained below, a single sample module S may be equipped with a plurality of small diameter sample chambers, for example by locating such chambers side by side and equidistant from the axis of the sample module (See FIG. **6**C). The tool can therefore take more samples before having to be pulled to the surface and can be used in smaller bores.

Referring again to FIGS. **1** and **2**, flow control module N includes a flow sensor **66**, a flow controller **68** and a selectively adjustable restriction device such as a valve **70**. A predetermined sample size can be obtained at a specific flow rate by use of the equipment described above in conjunction with reservoirs **72**, **73**, and **74**. Reservoir **74** is pressure balanced with approximately ⅓ wellbore pressure, by way of piston **71** and the reduced diameter of reservoir **73** relative to reservoir **74**. This is one example wherein wellbore fluid is used as a buffer fluid to control the pressure of fluid in flow line **54**, and the pressure of a sample being taken.

Sample chamber module S can then be employed to collect a sample of the fluid delivered via flow line **54** where the piston motion is controlled via the buffer fluid from the non-sample side of the piston being regulated by flow control module N, which is beneficial but not necessary for fluid sampling. With reference first to upper sample chamber module S in FIG. **2**, a valve **80** is opened and valves **62**, **62**A and **62**B are held closed, thus directing the formation fluid in flow line **54** into sample collecting cavity **84**C in chamber **84** of sample chamber module S, after which valve **80** is closed to isolate the sample. The tool can then be moved to a different location and the process repeated. Additional samples taken can be stored in any number of additional sample chamber modules S which may be attached by suitable alignment of valves. For example, there are two sample chambers S illustrated in FIG. **2**. After having filled the upper chamber by operation of shut-off valve **80**, the next sample can be stored in the lowermost sample chamber module S by opening shut-off valve **88** connected to sample collection cavity **90**C of chamber **90**. It should be noted that each sample chamber module has its own control assembly, shown in FIG. **2** as **100** and **94**. Any number of sample chamber modules S, or no sample chamber modules, can be used in particular configurations of the tool depending upon the nature of the test to be conducted. Also, sample module S may be a multi-sample module that houses a plurality of sample chambers, as mentioned above and described below.

It should also be noted that buffer fluid in the form of full-pressure wellbore fluid may be applied to the backsides of the pistons in chambers **84** and **90** to further control the pressure of the formation fluid being delivered to sample modules S. For this purpose, valves **81** and **83** are opened, and pump **92** of pump-out module M must pump the fluid in flow line **54** to a pressure exceeding wellbore pressure. It has been discovered that this action has the effect of dampening or reducing the pressure pulse or "shock" experienced during drawdown. This low shock sampling method has been used to particular advantage in obtaining fluid samples from unconsolidated formations.

It is known that various configurations of the apparatus A can be employed depending upon the objective to be accomplished. For basic sampling, the hydraulic power module C can be used in combination with the electric power module L, probe module E and multiple sample chamber modules S. For reservoir pressure determination, the hydraulic power module C can be used with the electric power module L, probe module E and precision pressure module B. For uncontaminated sampling at reservoir conditions, hydraulic power module C can be used with the electric power module L, probe module E in conjunction with fluid analysis module D, pump-out module M and multiple sample chamber modules S. A simulated Drill Stem Test (DST) test can be run by combining the electric power module L with packer module P, and precision pressure module B and sample chamber modules S. Other configurations are also possible and the makeup of such configurations also depends upon the objectives to be accomplished with the tool. The tool can be of unitary construction a well as modular, however, the modular construction allows greater flexibility and lower cost, to users not requiring all attributes.

As mentioned above, sample flow line **54** also extends through a precision pressure module B. Precision gauge **98** of module B should preferably be mounted as close to probes **12**, **14** or **46** as possible to reduce internal flow line length which, due to fluid compressibility, may affect pressure measurement responsiveness. Precision gauge **98** is more sensitive than the strain gauge **58** for more accurate pressure measurements with respect to time. Gauge **98** is preferably a quartz pressure gauge that performs the pressure measurement through the temperature and pressure dependent frequency characteristics of a quartz crystal, which is known to be more accurate than the comparatively simple strain measurement that a strain gauge employs. Suitable valving of the control mechanisms can also be employed to stagger the operation of gauge **98** and gauge **58** to take advantage of their difference in sensitivities and abilities to tolerate pressure differentials.

The individual modules of apparatus A are constructed so that they quickly connect to each other. Preferably, flush connections between the modules are used in lieu of male/female connections to avoid points where contaminants, common in a wellsite environment, may be trapped.

Flow control during sample collection allows different flow rates to be used. Flow control is useful in getting meaningful formation fluid samples as quickly as possible which minimizes the chance of binding the wireline and/or the tool because of mud oozing into the formation in high permeability situations. In low permeability situations, flow control is very helpful to prevent drawing formation fluid sample pressure below its bubble point or asphaltene precipitation point.

More particularly, the "low shock sampling" method described above is useful for reducing to a minimum the pressure drop in the formation fluid during drawdown so as to minimize the "shock" on the formation. By sampling at the smallest achievable pressure drop, the likelihood of keeping the formation fluid pressure above asphaltene precipitation point pressure as well as above bubble point pressure is also increased. In one method of achieving the objective of a minimum pressure drop, the sample chamber is maintained at wellbore hydrostatic pressure as described above, and the rate of drawing connate fluid into the tool is controlled by monitoring the tool's inlet flow line pressure via gauge **58** and adjusting the formation fluid flowrate via pump **92** and/or flow control module N to induce only the minimum drop in the monitored pressure that produces fluid flow from the formation. In this manner, the pressure drop is minimized through regulation of the formation fluid flowrate.

Turning now to FIG. **3**, one aspect of the present invention is schematically illustrated in the form of sample module SM adapted for use in a downhole tool such as the formation testing tool A described above. It should be noted, however, that the present invention exhibits utility in downhole tools other than a wireline-conveyed formation testing tool, such as in drill pipe strings and coiled tubing, although wireline tools are the presently preferred choice for use. Sample module SM includes sample chamber **110** for collecting a full-sized PVT sample of the formation fluid obtained via the downhole tool in accordance with the apparatus and method described above.

Sample chamber **110**, which is shown more particularly in FIG. **3**A, is itself an improvement over the art, and includes a substantially cylindrical steel alloy body **110***b* that is capable of safely withstanding reheating at the surface following withdrawal of the sample chamber from the wellbore to temperatures necessary to promote recombination of the sample components within the chamber. Such temperatures are typically no higher than 150° F., but may be as high as 400° F. in some conditions, such as when samples are taken from very deep wells. Surface reheating is typically accomplished through the application of heating tape to the exterior of the sample chamber or by immersing the chamber in a temperature-controlled reservoir or bath. Pressure is monitored during such heating through the connection of a gauge to a sealed port provided in the sample chamber. The primary means for the sample chamber to safely withstand such temperatures is to equip the chamber body with metal-to-metal seals **110***s* for isolating the samples collected therein, and to provide means such as, possibly, a relief valve or connection to the sample fluid or the buffer fluid with a pressure control device for bleeding off excess pressure that may develop within the chamber body when it's reheated at the surface.

Additionally, the sample chamber body **110***b* should be sufficiently equipped so as to be certified for transportation. Essentially, this requires that the sample volume be limited to 600 cc, and that a minimum ten percent gas cap exists inside the chamber body that protects the potentially volatile hydrocarbon contents collected therein in the event of impact to the body. The use of such gas cap charging is described further below.

Still further, it is desirable for sample chamber **110** to be equipped to store the sample collected therein for an indefinite period without substantial degradation of the sample. One solution for achieving this goal is for the sample chamber to include metal-to-metal seals **110***s* therein as the final shut-off seals for the sample collected therein, as mentioned previously. Thus, the use of metal-to-metal seals instead of elastomeric seals provides several advantages to sample chamber **110**.

Referring again to FIG. **3**A, sample module SM further includes validation chamber **112**, essentially a smaller version of sample chamber **110**, for collecting a substantially smaller sample of formation fluid than the larger full-sized sample chamber. In this regard, sample sizes on the order of 500–600 cc are collected in sample chamber **110** and 50–60 cc in validation chamber **112** are presently preferred, whereby the weight of the validation chamber is substantially reduced and it is safer to reheat at the well site compared to the sample chamber. Another particular advantage of the validation chamber is that it's removable from the sample module at the surface without disturbing the sample chamber, and, more particularly, the sample collected in the sample chamber. The validation chamber is also heatable to promote recombination of the sample fluid components that may have separated during withdrawal from the wellbore, but is not transportable since its contents will be examined at the well site to validate the full-sized sample collected in sample chamber **110**.

The smaller validation sample is taken downhole along with the larger "PVT" sample either sequentially or in parallel, and also may be displaced from the full size sample as well as taken separately from the full size sample. It is important, however, that the validation sample be taken at substantially the same time as the PVT sample to minimize variation between the two samples. In addition to being safer and easier to reheat than the much larger full-sized PVT sample, the validation sample is also much easier to promote recombination of its components through such heating on the surface. Typically, validation at the surface does not entail a full PVT analysis because the primary concern is contamination discovery. Because of this, the validation sample can either be maintained in single phase (again, meaning pressure compensated) or not.

Those skilled in the art will appreciate sample module SM can be combined to advantage with downhole tools, such as formation tester A, to improve the fluid sampling capabilities that such tools provide. In that regard, the present invention contemplates an improved downhole tool for obtaining reliable, high quality formation fluid samples that includes a probe assembly (see the description of probe modules E, F above, for example) for establishing fluid communication between the apparatus and a subsurface formation, and a pump assembly (see, for example, the description of pump-out module M above) for drawing fluid from the formation into the apparatus, in combination with improved sample module SM.

There are several different methods for achieving a high (PVT) quality sample and a validation sample. The most crucial attribute is that of maintaining a single phase sample from the time when the sample is taken (at least the PVT sample) to when it is analyzed. This is preferably accomplished by charging the sample with an inert gas which, by nature, loses much less pressure when the sample temperature drops during withdrawal of the sample chamber from the wellbore. The gas charging system can be contained in either the sample chamber itself or can be contained in the sample module, and preferably utilizes Nitrogen gas for charging purposes.

FIGS. **4** and **5** show two methods for gas charging. The concept of maintaining a gas cap on the back of a collected sample to minimize pressure reduction caused by cooling of the sample, and increase the likelihood of maintaining a "single-phase" sample, is schematically illustrated. In addition to facilitating recombination of the sample components under heating, a single-phase sample makes transferring of the sample, should it be needed, much safer for sample integrity. The concept of overcharging a collected fluid sample with gas is generally known, and is explained fully in U.S. Pat. No. 5,337,822, assigned to OilPhase Sampling Services, a division of Schlumberger, the contents of which patent are incorporated herein by reference.

FIG. **4** illustrate the use of a gas charge within sample chamber **110**. The gas charge is introduced beforehand via a port (not shown) in sample chamber **110** into pressurization cavity **120** and pressurizes a buffer fluid in cavity **122** through piston **121**. The buffer fluid in cavity **122** in turn pressurizes the sample in collection cavity **124** through piston **123**. In this example, the charging gas is charged to a set pressure before sample chamber **110** is run into the wellbore on a downhole tool depending on the expected well conditions. Sample chamber **110** may also include stop mechanisms (not shown, but described below in regard to FIGS. **14A–D**) which, upon closure of the sample chamber, permit either the charging gas in cavity **120** to move piston **121** or the buffer fluid in cavity **122** to move piston **123**. Either way, the pressure from the charging gas is utilized to control the sample fluid pressure in collection cavity **124** after the sample has been taken. Piston **123** includes elastomeric seals (labeled **110***e* in FIG. 3A), but since the buffer fluid and the collected sample are at the same pressure there is no pressure-induced migration of gases across the elastomeric seals.

The gas charge configuration can be rearranged in several different ways, two more of which are illustrated in FIGS. **5**A and **5**B. In these figures, the charging gas is located in sample module SM (not shown) within which sample chamber **110** is carried. The control mechanism for releasing the charging gas is also in the sample module and is activated when the sample section of the sample chamber has been closed through the action of one or more shut-off valves. These configurations allow for a smaller, less complicated sample chamber **110** because the gas control mechanism is located outside the chamber. FIG. **5**A illustrates piston **121** separating the charging gas in cavity **120** and the buffer fluid in cavity **122**, and piston **123** separating buffer fluid cavity **122** from formation fluid collection cavity **124**. FIG. **5**B shows an alternative configuration wherein nitrogen gas NG is charged directly into the pressurization cavity, whereby it mixes with buffer fluid BF to charge sample fluid in cavity **124** as desired.

There are other methods for maintaining pressure on a sample such as an electromechanical system which senses the pressure via a pressure gauge (not shown) sensing the pressure of cavity **124** and acts to maintain the pressure above a set limit. Such methods are contemplated by and within the scope of the present invention, but are not described further herein.

In order to allow wiring and fluid flow lines to pass through the sample module, there are certain design constraints on the sample chambers. There are two basic methods of designing the sample module. One module, referred to as SMa, can be thought of as a canoe style module and the other module, referred to as SMb, can be considered an annular style module. The two basic concepts are shown respectively in FIGS. **6**A and **6**B, along with variation SMc of the canoe style concept with multiple sample chambers in FIG. **6**C.

Canoe style module SMb is equipped with a U-shaped channel for receiving the elongated cylindrical sample chamber **110***b*, and permits sample chamber **110***b* to be much simpler in design (essentially a tubular pressure vessel), allowing the sample chamber to be a more cost effective transport and storage vessel. However, the canoe style module makes a more complicated carrier due to the routing of the power/control/communication wiring passage **154***b* and flowline **54***b* as seen in FIG. **6**B.

The annular style module SMa, on the other hand, makes the routing of wiring and fluid passages **154***a* and **54***a* simpler, but complicates the sample chamber **110***a* as shown by the tube within a tube within a tube design of FIG. **6**A. In this embodiment, sample fluid is collected in annulus cavity **124***a*.

FIG. **6**C shows the canoe style sample module expanded to allow multiple sample chambers **110** within the confines of respective U-shaped channels. Again, the canoe style module makes a more complicated carrier due to the routing of the wiring passage and flowline passage (neither of which are shown here), but a simpler, removable sample chamber.

As mentioned above, sample chamber **110** must be transportable, meaning it must meet the design requirements of transportation regulating agencies such as the U.S. Department of Transportation and Transport Canada, as well as others having jurisdiction over the region(s) wherein the tool is used. The sample chamber is also designed to serve as an acceptable storage container. To achieve these goals, no elastomeric seals are used to maintain sample pressure after the chamber is shut in by an operator when the tool reaches the surface. Thus, the present invention entails minimizing or eliminating any elastomeric seals which hold the pressurized sample. The final shut-in seals that are actuated either downhole or on the surface after the sample is taken should all be metal-to-metal so that gases do not migrate across the seals thereby disrupting the actual sample components. Minimizing elastomeric seals will also make the container safer for heating because elastomeric seals are not adequate for long heating/pressure cycles, although the use of elastomeric seals that are pressure balanced, such as by buffer fluid, in contact with the sample is permitted.

Along with being transportable and storable, sample chamber **110** must be heatable to reservoir conditions and, as such, the design safety factors must allow for safe heating of the vessel to temperatures up to 400° F. at pressures up to

25,000 psi). A pressure relief system (see, for example, the relief valve shown in FIG. **9**B) may be incorporated if needed to mitigate the potential safety hazard of an over-pressurized chamber. The preferred method for such a system is to monitor the pressure within the sample chamber and provide the ability to manually bleed off fluid pressure through a connection to the chamber.

The sample chamber also allows a formation fluid sample to be taken at a minimum pressure drop just below reservoir pressure, and then raised to a pressure at or above reservoir pressure, in some cases substantially above reservoir pressure and even above wellbore pressure. The latter requirement entails that there is a buffer fluid at or above reservoir pressure against which the sample must be pumped, as described above in regard to formation testing tool A. The sample chamber may also need to allow the buffer fluid to be channeled to a device that can control the fluid flow so that the rate of the sample being taken can be controlled and therefore the buffer fluid must be routed back into the flow line.

FIG. **7** schematically illustrates sample module SM and sample chamber **110** having a buffer fluid in cavity **122** in pressure communication via piston **123** with the sample collected in cavity **124** so that the pressure drawdown on the sample can be minimized. This can be done by putting the buffer fluid in communication with hydrostatic wellbore pressure (Low Shock Sampling), by routing the buffer fluid to a conventional flow regulator carried by sample module SM, or by routing the fluid to the flow line and regulating with a flow control module like module N described above for tool A.

"Dead volume" refers to the volume of fluid or gas which is contained in the fluid flow lines and the sample chambers which does not get extracted when the sample is taken. In other words, it is superfluous volume that is trapped in communication with the sample during sample collection. This dead volume fluid or gas is therefore mixed in with the sample fluid and contaminates the sample. In the described design, some dead volume is practically unavoidable, but it is desirable to minimize this volume to ensure a PVT quality sample.

The sample module and sample chamber of the present invention also minimize "dead volume" and prevent the loss of gas when shut in. Dead volume fluid typically consists of air or some other fluid such as water, which is generally used to prefill the flow lines in sample module SM. Dead volume is primarily minimized by limiting the length of flow line between isolating valves and the sample and validation chambers, as well as by minimizing the flow line length between these chambers. FIG. **8** shows a span of dead volume fluid defined by the flow line length between shut-off valves **130** and **132**, which length the present invention minimizes to avoid sample contamination. Examples of different embodiments that minimize dead volume are shown below.

While sampling, it is usually desirable to take at least two if not three PVT quality samples in the same zone at the same time. Therefore, sample module SM should allow multiple sample chambers **110** to be filled at the same sampling depth. It is preferable that the sample module include at least two PVT sample chambers **110** for filling with formation fluid at each sampling point. The chambers can be filled either in series (one after the other) or in parallel. The distance between their entrance ports shall be minimized in order to ensure the similarity of the fluid entering each chamber, and to minimize dead volume.

Several possible combinations of PVT sample chambers and validation sample chambers are shown in FIGS. **9** through **12**. FIGS. **9**A and **9**B illustrate two alternative embodiments for arranging sample chamber **110** and validation chamber **112** for sequential, or serial, filling thereof. Sequential filling refers to the fact that one sample chamber is filled prior to another chamber.

FIG. **9**A shows the concept fulfilled by placing an outlet port **140** near the end of the stroke of sample piston **123** such that collection cavity **124** of sample chamber **110** will completely fill before outlet port **140** is opened to fluid pressure provided via flow line **54** and the sample starts filling validation chamber **112**.

FIG. **9**B shows relief valve **142** placed in the buffer fluid outlet line **144** of validation chamber **112**. Relief valve **142** is designed to remain closed, thereby preventing fluid flow into validation sample collection cavity **124***v*, until the sample in cavity **124** of sample chamber **110** is pressurized above the relief valve relief-pressure setting. This will cause the full size sample chamber **110** to fill before smaller validation chamber **112**. It should be noted that the serial filling configuration of FIG. **9**B results in more dead volume than that of FIG. **9**A, wherein dead volume is minimized, due to increased flow line length in the embodiment of FIG. **9**B.

FIGS. **10**A and **10**B illustrate two alternative embodiments for arranging sample chamber **110** and validation chamber **112** for parallel filling thereof. Parallel filling refers to the process of allowing both chambers to fill substantially simultaneously.

In FIG. **10**A, chambers **110** and **112** are filled in parallel by opening seal valve **150** and shut-off valves **146** and **148** to permit fluid in flow line **54** to fill respective collection cavities **124** and **124***v*. Buffer fluid cavities **122** and **122***v* are open to buffer fluids having substantially the same pressure, or to the same buffer fluid source, resulting in substantially simultaneous filling of chambers **110** and **112**.

FIG. **10**B shows an alternative parallel filling configuration which will decrease the amount of dead volume as compared to the embodiment of FIG. **10**A because of the compact arrangement of the fluid flow lines and valves **150**, **146**, and **148**. In the particular configuration shown, validation chamber **112** has been inverted from its orientation in FIG. **10**A to accommodate the central placement of shut-off valves **146** and **148**.

In practice, parallel filling arrangements will most likely result in one chamber filling before the other due to differences in friction. Therefore, this method could technically be considered sequential, but the order of chamber filling is not forced like in the pure sequential modes shown in FIGS. **9**A and **9**B.

Most sample chamber designs utilize at least one piston for several reasons, including minimizing the dead volume, controlling the pressure drop on the sample, easing extraction the sample for analysis, and for simplifying the design. FIGS. **11**A–C illustrate schematically a sample module arrangement wherein validation chamber **112** is provided with no pistons therein. FIG. **11**A shows sample chamber **110** arranged serially with validation chamber **112** via flow line **54**. Shut-off valves **152**, **148**, and **146** are all open, and seal valves **150** and **151** are set to permit flow through validation chamber **112** and seal valve **150** whereby no fluid is directed into sample chamber **110**.

In FIG. **11**B, seal valve **150** has been set to direct fluid flowing through validation chamber **112** into fluid collection cavity **124** of sample chamber **110**. In this figure, piston **123** has been moved from the bottom of sample chamber **110** to a level approximately halfway up the chamber's internal volume, expelling buffer fluid in cavity **122**.

Once piston **123** is moved upwardly to its full extent within sample chamber **110**, seal valve **151** is set to direct fluid in flow line **54** to bypass validation chamber **112** and sample chamber **110**. This action, shown in FIG. **11**C, has the effect of shutting in the samples collected within chambers **112** and **110**. Shut-off valves **152**, **148**, and **146** may also be closed at this time as desired.

FIG. **12** shows that multiple sample chambers can be filled from one flow line **54** to capture multiple samples of reservoir fluids from one sampling point simultaneously. The arrangement includes three full-sized sample chambers **110** and one validation chamber **112** connected in parallel with appropriate flow lines and valving. Those skilled in the art will appreciate that such a multiple chamber arrangement could be connected sequentially as well.

It will also be appreciated that FIGS. **9**–**12** do not show gas charge for simplification. In practice, the PVT sample chambers **110** will be provided with a gas charge pressurization system to control the pressure of the collected samples, while the validation chamber may or may not have a gas charge system.

FIGS. **13**A–D are schematic illustrations of the steps for sequentially filling a sample chamber, shutting in the sample chamber, using a separate gas charging chamber for extracting a portion of the sample from the sample chamber to the validation chamber, and shutting in both the sample and validation chambers. These figures illustrate but one of many possible arrangements of a gas charging module which functions as a pressurization system. This arrangement allows the validation sample to be displaced directly from the full sized sample chamber **110**. The chambers in this arrangement can be inverted so that the sample comes in from the top instead of the bottom, although the orientation shown is preferred. These arrangements show schematically one embodiment of the associated flow lines, seal valves, and shut-off valves for controlling the pressure of a collected sample with a charge of compressed gas, such as Nitrogen. It is also known in the art to equip sample chamber **110** with a self shut-off mechanism which could reduce the amount of valves necessary to isolate the sample chambers from the flow line. There are also design concepts for multi-directional seal valves which could further reduce the number of valves needed.

In FIG. **13**A, formation fluid is flowing through flow line **54** past seal valve **150** and shut-off valve **146** into collection cavity **124**. Valve **162** is closed at this time. In FIG. **13**B, sample chamber **110** is filled, as seen by fully elevated piston **123**, which becomes hydraulically stopped from further travel because the buffer fluid in cavity **122** can no longer escape through outlet valve **156**. At this time, outlet valve **156** is closed, and seal valve **150** is closed to flow line **54** but opened to flow line **54***a*, interconnecting fluid collection cavities **124** and **124***v*. In FIG. **13**C, valves **162** and **158** are opened, permitting the fluid pressure in flow line **54** to fill cavity **164** of gas charge chamber **160**, forcing gas in chamber **166** through valve **158** into pressurization cavity **120**. This has the effect of urging pistons **121** and **123** downwardly, forcing fluid in collection cavity **124** out through valves **146**, **150**, and **148** into collection cavity **124***v* of validation chamber **112**. Then, in FIG. **13**D, valves **162** and **158** are closed, shutting in the collected samples within chambers **110** and **112**. Valve **148** may also be closed at this time as desired.

FIGS. **14**A–D show another configuration of arranging sample chamber **110**, validation chamber **112**, and gas charging chamber **160**, with the chambers being disposed in sample module SM and the gas charging chamber being disposed within gas charge module GM. In this configuration, both chambers **110** and **112** are pressure-controlled with a gas charge and are filled in parallel. It will be appreciated that this configuration can be expanded to include multiple full size chambers and/or validation sample chambers filling at the same time within sample module SM.

In FIG. **14**A, pump-out module M (described above) pressurizes the formation fluid in flow line **54**. The formation fluid is drawn from the formation using probe module E and/or F and is initially flushed through flow line **54** into the borehole via outlet valve **170**. Buffer fluid present in cavities **122** and **122***v* is open to borehole pressure at this time by opening valves **176**, **178**, and **180**, which urges pistons **121** and **121***v* to their uppermost position against stops **174** and **174***v*. In fact, borehole fluid may be used as the buffer fluid.

Referring now to FIG. **14**B, once contaminants have been sufficiently flushed out of the fluid in flow line **54**, outlet valve **170** is closed and fluid from flow line **54** is directed through seal valve **150** and shut-off valve **146** into collection cavity **124** of sample chamber **110**. Similarly, fluid is also directed in parallel flow through seal valve **152** and shut-off valve **148** into collection cavity **124***v* of validation chamber **112**. For this to occur, pump-out module M must overcome the wellbore pressure the acts on pistons **123** and **123***v*. Thus, the fluid in flow line **54** must be pumped to a pressure greater than wellbore pressure, which action causes the filling of collection cavities **124** and **124***v* and forces pistons **123** and **123***v* against respective stops **172** and **172***v*. This also expels portions of the buffer fluid present in cavities **122** and **122***v*. This is the Low Shock Sampling process, also described above.

In FIG. **14**C, the collected samples are shut in by closing seal valves **150**, **152**, and **178**. Valves **158**, **159**, and **161** are opened, permitting fluid in flow line **54** to urge the piston in gas charging chamber **160** downwardly, charging cavities **120** and **120***v* with Nitrogen gas. This urges pistons **121**, **123**, **121***v*, and **123***v* downwardly to compress the samples collected in cavities **124** and **124***v*.

In FIG. **14**D, the samples have been further compressed due to cooling of the sample as it comes to surface, as indicated by the additional downward movement of pistons **121**, **123**, **121***v*, and **123***v*. Valves **158**, **176**, **146**, **148**, **180** and **161** are closed manually after withdrawal. At some point prior to removal of chambers **110** and **112** from module SM, valve **159** must also be closed. Although valve **159** is shown as an electrically controlled seal valve, it may alternatively be a manual shut-off valve. The sample chambers are now at the surface, and the samples in cavities **124** and **124***v* have shrank from cooling during withdrawal from the wellbore. Gas in pressurization cavities **120** and **120***v* has expanded to maintain constant pressure the collected samples, keeping the samples in "single phase."

FIG. **15** is a schematic illustration of an alternative sample module SM incorporating gas charging chamber **160** that pressurizes buffer fluid **122**, **122***v* in respective sample and validation chambers **110**, **112** independently of fluid flow line **54** in the sample module.

It should be further noted that all of the sample chambers, PVT and validation, will have a mechanism which promotes agitation of the fluid in order to facilitate recombination of the sample components at the surface. This mechanism may be as simple as a solid slug or dense non-miscible liquid inside the sample chamber which will, when shaken or inverted, fall through the sample to promote mixing. This mechanism may also be a stirring mechanism attached to the chamber, or a magnetic stirring system. If an external system is developed which can agitate without contacting the sample, such as ultrasonic, the mechanism in the sample chamber may be left out of the design.

In view of the foregoing it is evident that the present invention is well adapted to attain all of the objects and features hereinabove set forth, together with other objects and features which are inherent in the apparatus disclosed herein.

Existing sampling tools do not satisfactorily address all of the issues involved in bringing a high quality reservoir sample to the surface. This new module will be superior to existing modules in this area. This module can be run in either open or cased holes with no dependence on the means of conveyance.

As will be readily apparent to those skilled in the art, the present invention may easily be produced in other specific forms without departing from its spirit or essential characteristics. The present embodiment is, therefore, to be considered as merely illustrative and not restrictive. The scope of the invention is indicated by the claims that follow rather than the foregoing description, and all changes which come within the meaning and range of equivalence of the claims are therefore intended to be embraced therein.

What is claimed is:

1. A sample module for use in a downhlole tool to obtain fluid from a subsurface formation penetrated by a wellbore, comprising:

a sample chamber carried by the module for collecting a sample of formation fluid obtained from the formation via the downhole tool; and

a validation chamber carried by the module, the validation chamber being smaller than said sample chamber and capable of collecting a representative sample of the formation fluid collected by said sample chamber;

wherein said validation chamber is independently removable from the sample module and adapted for evaluation of said representative sample at the surface whereby the viability of the sample of formation fluid in said sample chamber is determined without disturbing said sample chamber.

2. The sample module of claim **1**, wherein said sample chamber and said validation chamber are placed in parallel fluid communication with a sample fluid flowline in the downhole tool such that said chambers may be filled substantially simultaneously.

3. The sample module of claim **1**, wherein said sample chamber and said validation chamber are placed in serial fluid communication with a sample fluid flowline in the downhole tool such that said chambers may be filled consecutively.

4. The sample module of claim **1**, wherein said sample chamber is adapted for maintaining the sample stored therein in a single phase condition as the sample module is withdrawn with the downhole tool from the wellbore.

5. The sample module of claim **1**, wherein said sample chamber and said validation chamber are adapted for maintaining the fluid samples stored therein in a single phase condition as the sample module is withdrawn with the downhole tool from the wellbore.

6. The sample module of claim **1**, wherein said chambers are capable of safely withstanding heating at the surface, following collection of samples and withdrawal of the sample module from the wellbore, to temperatures necessary to promote recombination of the sample components within said chambers.

7. The sample module of claim **6**, wherein each of said chambers includes metal-to-metal seals isolating the samples collected in said chambers, and means for bleeding excess pressure that develops in said chamber during heating.

8. The sample module of claim **1**, wherein said sample chamber is sufficiently equipped so as to be certified for transportation.

9. The sample module of claim **8**, wherein said sample chamber includes a sample collection cavity, the volume of which does not exceed 600 cc, and said sample chamber includes means for charging the sample collected within said sample chamber with a minimum gas cap of ten percent by volume.

10. The sample module of claim **1**, wherein said sample chamber is adapted for storing the sample collected therein for an indefinite period without substantial degradation of the sample.

11. The sample module of claim **10**, wherein said sample chamber includes metal-to-metal seals therein as final shut-off seals for isolating the sample collected therein.

12. A sample chamber for use in a downhole tool to obtain fluid from a subsurface formation penetrated by a wellbore, comprising:

a substantially cylindrical body capable of safely withstanding heating at the surface, following collection of a formation fluid sample via the downhole tool and withdrawal of the sample chamber from the wellbore, to temperatures necessary to promote recombination of the sample components within said chamber, said body being sufficiently equipped so as to be certified for transportation;

a floating piston slidably positioned within said body so as to define a fluid collection cavity and a pressurization cavity, whereby the pressurization cavity is charged with a minimum ten percent gas cap by volume to control the pressure of the sample collected in the collection cavity; and

metal-to-metal seals extending through the cylindrical body that serve as final shut-off seals for the sample collected in the collection cavity of said body.

13. An apparatus for obtaining fluid from a subsurface formation penetrated by a wellbore, comprising:

a probe assembly for establishing fluid communication between the apparatus and the formation when the apparatus is positioned in the wellbore;

a pump assembly for drawing fluid from the formation into the apparatus;

a sample chamber for collecting a sample of the formation fluid drawn from the formation by said pumping assembly; and

a validation chamber smaller than said sample chamber, said validation chamber being capable of collecting a representative sample of the formation fluid in said sample chamber, said validation chamber being independently removable from the apparatus at the surface for evaluation of said representative sample whereby the viability of the formation fluid collected in said sample chamber is determined at the wellbore without disturbing said sample chamber.

14. The apparatus of claim **13**, wherein said sample chamber is adapted for maintaining the sample stored therein in a single phase condition as the apparatus is withdrawn from the wellbore.

15. The apparatus of claim **14**, wherein said sample chamber includes a floating piston slidably positioned within said sample chamber so as to define a fluid collection cavity and a pressurization cavity, the apparatus further comprising:

a flow line establishing fluid communication between said probe assembly, said pump assembly, and the fluid collection cavity of said sample chamber; and

a pressurization system for charging the pressurization cavity to control the pressure of the collected sample fluid within the collection cavity via the floating piston.

16. The apparatus of claim **15**, wherein said pressurization system includes a valve positioned for fluid communication with the pressurization cavity of said sample chamber, the valve being movable between positions closing the pressurization cavity and opening the pressurization cavity to a source of fluid at a greater pressure than the pressure of the formation fluid delivered to the collection cavity.

17. The apparatus of claim **16**, wherein said pressurization system controls the pressure of the collected sample fluid within the collection cavity during collection of the sample from the formation.

18. The apparatus of claim **17**, wherein the source of fluid at a greater pressure than the pressure of the collected sample fluid is wellbore fluid.

19. The apparatus of claim **16**, wherein said pressurization system controls the pressure of the collected sample fluid within the collection cavity during retrieval of the apparatus from the wellbore to the surface.

20. The apparatus of claim **19**, wherein the source of fluid at a greater pressure than the pressure of the collected sample fluid is a source of inert gas carried by the apparatus.

21. The apparatus of claim **13**, wherein the apparatus is a wireline-conveyed formation testing tool.

22. A method for obtaining fluid from a subsurface formation penetrated by a wellbore, comprising:

positioning an apparatus within the wellbore;

establishing fluid communication between the apparatus and the formation;

inducing movement of fluid from the formation into the apparatus;

delivering a sample of the formation fluid moved into the apparatus to a sample chamber for collection therein;

delivering a representative sample of the formation fluid moved into the sample chamber to a validation chamber for collection therein, the validation chamber being smaller than the sample chamber;

withdrawing the apparatus from the wellbore;

removing the validation chamber from the apparatus without disturbing the sample chamber; and

evaluating the representative sample whereby the viability of the sample in the sample chamber is determined.

23. The method of claim **22**, wherein the formation fluid samples are delivered to the sample chamber and the validation chamber substantially simultaneously.

24. The method of claim **22**, wherein the formation fluid samples are delivered to the sample chamber and the validation chamber consecutively.

25. The method of claim **22**, further comprising the step of maintaining the sample stored in the sample chamber in a single phase condition as the apparatus is withdrawn from the wellbore.

26. The method of claim **25**, wherein the sample chamber includes a floating piston slidably positioned therein so as to define a fluid collection cavity and a pressurization cavity, and the sample of the formation fluid moved into the apparatus is delivered to the collection cavity, the method further comprising the step of charging the pressurization cavity to control the pressure of the sample delivered to the collection cavity.

27. The method of claim **26**, wherein the pressurization cavity is charged to control the pressure of the sample fluid within the collection cavity during collection of the sample from the formation.

28. The method of claim **27**, wherein the pressurization cavity is charged by wellbore fluid.

29. The method of claim **26**, wherein the pressurization cavity is charged to control the pressure of the sample fluid collected within the collection cavity during retrieval of the apparatus from the wellbore to the surface.

30. The method of claim **29**, wherein the pressurization cavity is charged by a source of inert gas.

31. The method of claim **22**, further comprising the step of maintaining the samples stored in the validation chamber and the sample chamber in a single phase condition as the apparatus is withdrawn from the wellbore.

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